PROGRAM OVERVIEW, MAIN PROGRAM, AND SUBROUTINE DYN

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The N-BOD2 User's and Programmer's Manual

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THE N-BOD2 USER'S AND PROGRAMMER'S MANUAL

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INTRODUCTION

The general purpose digital program N-BOD, and its present version N-BOD2, have been developed with the needs of the spacecraft attitude dynamicist foremost in mind. This fact, however, does not detract in any way from its applicability to a much broader class of problems. The program may be used to both derive and output in a vector-dyadic form, and/or to solve numerically the equations of motion of any system that may be adequately modeled, for the purposes of dynamic simulation, as a topological tree of point-connected rigid bodies, flexible bodies, point masses, and symmetrical momentum wheels (commonly called "symmetric wheel" in this document).

The underlying theoretical development upon which the program N-BOD2 is based may be found in References 1 and 2. In the FORTRAN IV coding of this program, a definite attempt has been made to draw a balance between available generality, ease of user operation, and computational speed and efficiency.

The program is structured to expand or contract with the required needs of the user. By an internal interrogation of the input data, the program sets up a series of logic flags that determine the computational options that should be used and those that should not.

In most practical problems, the user will be required to interface with the program. The output routine, which is called every integration step, prints virtually all system state variables along with numerous other physically meaningful parameters that are useful for initial check-out purposes. In setting up the output routine for production runs, the user is expected to literally delete the unwanted print statements from the output subroutine and insert his own.

If external forces and torques act on the system or if nongyroscopic forces and torques act internal to the system at hinge points, the user is required to define them. This will present no particular problem since a number of examples are provided which show exactly how most commonly occurring forces and torques are defined and coded.

Frequently programs already exist that define, for example, the workings of a complex attitude control system. State-variable information is required as input to it and motor torques are outputted from it. By a few simple interface statements, which create the proper state-variable parameters for the existing torque routine and the required force and torque parameters for N-BOD2, the debugged routine may be inserted in total into N-BOD2.

The input of data is provided for in three separate subroutines which are called sequentially. The first is of a rigid format. In this routine a basic coupled rigid body, point mass, and symmetric wheel model of the system is described. Connection topology, degrees of freedom, mass, inertia, and geometric parameters, along with relative body orientation and initial kinematic conditions, are inputted here. The second input routine is more flexible. Numerous options are available and may be called for by use of option cards. For example, some of the bodies may be redefined to be flexible; if so, the flexible body data would be inputted at this point. The third input routine is for the user. Any data that will be required for the torque and output routines, written by the user, are entered here. It may be left empty, or again the user may insert an existing input routine and set up the proper interface statements. It is permissible, and at times is convenient, for the user to use this routine to override some data already inputted in the first input routine.

When the analyst is first presented with a particular problem for dynamic simulation, he is usually provided with just enough information to create a topological model, define the character of each body in the model (rigid body, flexible body, point mass, or symmetric wheel), and to define the number of degrees of relative freedom between contiguous bodies. With this information and a fictitious set of mass and inertia properties, the user may obtain the equations of motion for the simulation model. At times, this is the end product.

With the outputted equations of motion, the user will immediately recognize familiar terms and will need only a cursory glance at the rather lengthy symbol list for exact definitions. There is a one-for-one correspondence between the outputted equations and those provided in References 1 and 2. For example, the outputted statements

$$FOMC(5) \times (XIC(5) \cdot FOMC(5))$$

and

$$FOMC(3) \times (FOMC(3) \times CAC(3))$$

translate to the familiar vector tensor expressions

$$\vec{\omega}_{s} \times (\Phi_{s} \cdot \vec{\omega}_{s})$$

and

$$\vec{\omega}_3 \times (\vec{\omega}_3 \times \vec{\alpha}_3)$$

respectively.

To use this program effectively, the user must become familiar with the array names used to define the various physical characteristics and state variables in the equations of motion. This is most easily done by a study of the computer derived equations of motion. Once this is done the user is in a position to proceed to code the required input, torque, and output routines for his particular problem and to make use of the full power of N-BOD2.

THE SIMULATION MODEL

The analysis of the dynamic characteristics of a complex system is usually done through the study of a simulation model. The simulation model must possess the same dynamic characteristics as the complex system and at the same time be amenable to mathematical analysis.

Rigid bodies, point masses, and symmetric wheels are idealized bodies that readily lend themselves to mathematical analysis. Flexible bodies are more complex; however, if the deformation is small and the laws of linear elasticity can be applied, the dynamic characteristics can be simulated by the natural modes and frequencies of vibration, the determination of which is a subject in itself. { N-BOD2 simply assumes that the modes and frequencies of flexible bodies are obtainable; it accepts only resultant mode-dependent parameters in the input data stream (see Appendix B).]

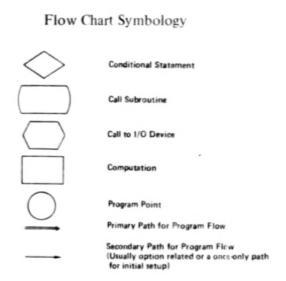
N-BOD2 assumes that the complex system under study may be simulated by a model comprised of rigid bodies, point masses, symmetric wheels, and flexible bodies for which natural modes and frequencies of vibration are available. Contiguous rigid and flexible bodies are assumed to be point connected in such a man ser that the total system forms a topological tree (no closed paths). Furthermore, point masses are assumed to exist only at limb ends while symmetric wheels are assumed to be imbedded within either rigid or flexible bodies.

The present version of N-BOD2 has certain *limitations* with respect to the simulation of flexible bodies. The author has not coded the equations required to allow hinge points and wheel attachment points on flexible bodies to be time varying in the flexible body's body-fixed reference frame. This will be done if future simulation demands require it. It should be noted that the equations exist and can be found in Reference 2, in a form amenable for inclusion into N-BOD2.

The simulation model must reflect the fact that relative motion between contiguous bodies may be kinematically constrained. To do this, N-BOD2 assumes that contiguous rigid and flexible bodies are connected together by physically realizable 0-, 1-, 2-, or 3-degrees-of-freedom gimbals. The gimbals prohibit relative translational motion and permit, at most, 3 degrees of relative rotational freedom at hinge points. Point masses may have 0, 1, 2, or 3 degrees of relative translational freedom and symmetric wheels may have 1 degree of rotational freedom relative to the body in which they are imbedded. Flexible bodies may possess several degrees of vibrational freedom in addition to the degrees of freedom associated with the connection gimbals. Practical computer storage and speed limitations put a limit on the total number of vibrational modes allowed for the total system of coupled bodies.

PROGRAM OVERVIEW, MAIN PROGRAM, AND SUBROUTINE DYN

The basic flow logic of the program N-BOD2 is shown on the flowchart in figures 1 and 2 using the symbology listed below. Immediately upon entry into the MAIN program a single control card is read. The data on this card sets several logic flags that control the mode of data input and output.



The input data may either define the physical and kinematic parameters for a new job that will start at time zero, or define the parameters needed to restart the program at the termination time of a previous run.

The output data may either be a listing of the system equations of motion or the output of selected system state variables. Upon reaching the termination time of a particular job, a restart tape may be requested. This tape contains all data required to restart the job at a later date.

If a restart run is to be made, the restart tape created at the end of a previous run becomes the input tape for the present run. It contains the magnitude of every computer-generated parameter required for a reinitiation of computation. The tape is read in and the program then immediately branches to the start of the integration loop and proceeds as if the previous run had never been terminated.

If a new run starting at time zero is to be made, three input subroutines are sequentially called. The first called is INBS. In this subroutine, the basic system is defined. The data are checked in INEROR for physical realizability, and then subroutine SETS is entered. In SETS, various integer sets are computed that enable the program to avoid redundant and trivial computation. Subroutine INOPT, the second input routine, is programmed to recognize various option codes. The available options fall into two categories: those that expand modeling capability, e.g., flexible body option, caged degree of freedom option; and those that attempt to

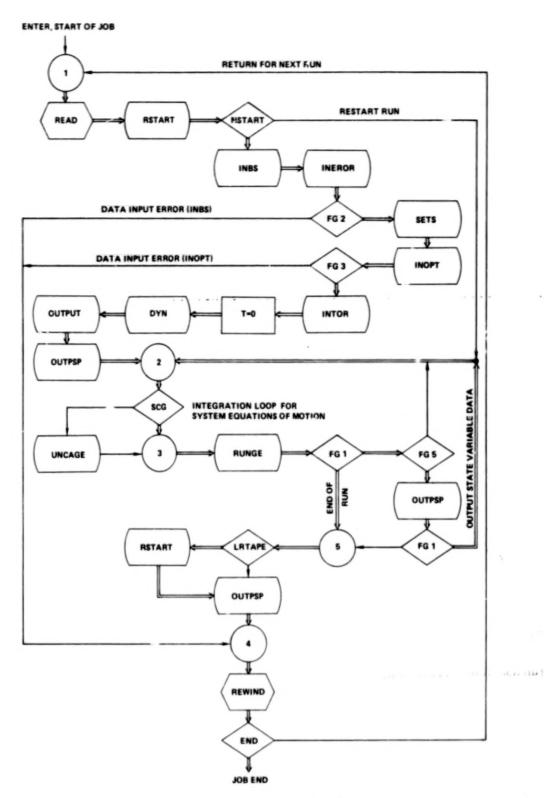


Figure 1. Main program flowchart.

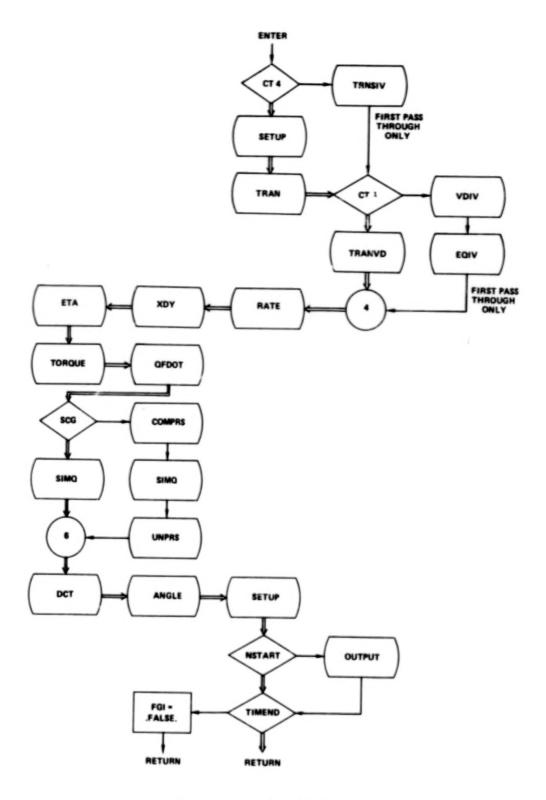


Figure 2. Subroutine DYN flowchart.

improve computational efficiency and run time by allowing the user to introduce engineering judgment in deleting computations that he feels will have a negligible impact upon computed results. The last input routine is INTOR. Normally this routine is empty. It is inserted for the user. Any input data that the user requires for a description of the nongyroscopic forces and torques acting on this system are entered here according to a user written code. The user's input data should be stored in common block /SATELL/ which is reserved for the user. Normally, it contains an empty dummy array of 1000 real double precision words.

With all necessary input data stored in computer memory, subroutine DYN is entered for the first time. The complete state of the system is computed at time zero and outputted. The primary integration loop is then entered. RUNGE is the integration package; it is a fixed-step, four-order Runge Kutta numerical integration routine that calls DYN to compute the equations of motion to be integrated.

At the end of each integration loop, a check is made to determine if the output routine OUTPSP should be entered. At the termination time (a flag is reset in DYN), the program branches out of the integration loop, creates a restart tape if called for, and terminates if there is no succeeding run to follow.

Subroutine DYN is used to call the subroutines in which the equations of motion are coded. Upon entry, a check is made to see if it is the first pass through; if so, sertain initialization procedures must be carried out. Initial values for transformation matrices are obtained by TRNSIV; initial values for all vectors and dyads are obtained by VDIV; and initial values for all differential equations are defined in EQIV. If it is not the first pass through DYN, the call for DYN has been made by RUNGE. All of the system state variables obtained from RUNGE are sorted out in SETUP. TRAN computes all transformation matrices; TRANVD transforms all vectors and dyads to a common frame of computation; RATE computes all rate related vectors; XDY computes all inertia and pseudo inertia tensors on the left-hand side of the system equations of motion; and ETA computes all gyroscopic cross coupling torques found on the right-hand side of the equations.

Subroutine TORQUE is user defined; all nongyroscopic forces and torques are defined here in vector form. To reduce the equations to a set of simultaneous scalar equations, QFDOT is called. Upon exit, a check is made in DYN to see if any degrees of freedom are caged. Appropriate action is taken by COMPRS if they are caged, and the simultaneous equations are solved by SIMQ. All acceleration parameters are now at hand. DCT is then entered to get the derivatives of the direction cosine matrices, and ANGLE is entered to get the equations that define relative displacement. All differential equations are then stacked in a one-dimensional array by SETUP in a form acceptable to RUNGE and return to RUNGE is made after a time check.

PROGRAMMING TECHNIQUES USED

A definite attempt has been made to reflect as much of the subscript notation as possible that is used in References 1 and 2 in the FORTRAN IV coding of the equations. Deviations from this practice occur at points where a more streamlined subscript notation leads to a considerable saving in computer storage and an increase in computational speed. It should be realized that computation speed is severely compromised by the unnecessary use of multi-dimensioned arrays.

N-BOD2 is built on the basis that the only labeling which should be done by the user is the labeling of bodies and wheels. All other required labeling is done by the computer. The user, however, must be aware of the labeling rules that are used internally if he is to effectively interface with the program.

Table 1 provides a listing of the symbol names used in the coding of N-BOD2, their dimension, type, storage location, and a very brief description of each along with the subroutine in which they are first defined and/or used extensively. A detailed definition of each symbolic name may be found in the comment cards of the subroutine and/or in the subroutine discussion included in this report.

PROGRAMMER'S GUIDE TO MAIN PROGRAM AND SUBROUTINE DYN

The purpose of the MAIN program and subroutine DYN is to sequentially call the primary special purpose subroutines that read input data, define and integrate the equations of motion, and write output data. A detailed discussion of the flow logic is provided in the section entitled "Program Overview, MAIN Program, and Subroutine DYN."

The following variables defined in table 1 are either first introduced or used extensively in the MAIN program and subroutine DYN.

CT4 – a counter. Used to count the number of passes through subroutine DYN. It is updated upon entry into DYN. The fourth order fixed step Runge Kutta integration routine calls DYN four times per integration step, consequently

$$CT4 = 1 + 4 * (N - 1) + J$$

during and after the Jth pass through DYN of the Nth integration step.

FG1 – end of job flag. At the end of each integration step its status is checked in MAIN. If .TRUE., computation continues; if .FALSE., an end-of-run condition has been satisfied. If T.GE.TIMEND in DYN, FG1 is reset to .FALSE. The user may define any other end-of-run condition he desires in subroutines TORQUE or OUTPSP.

Table 1 Symbol Names Used in N-BOD2

```
C
C
C
C
      N-BOD2 IS DIMENSIONED TO ACCEPT A MAXIMUM OF
        N - BODIES (FLEXIBLE BODIES + RIGID BODIES + POINT MASSES)
Û
       N - SYMMETRIC WHEELS
      2N - FLEXIBLE MODES OF VIBRATION (TOTAL FOR ALL FLEXIBLE BODIES)
C
C
      4N - MODAL CROSS-COUPLING COEFFICIENTS (TOTAL)
C
      33 - INDEPENDENT DEGREES OF FREEDOM
C
      160 - FIRST ORDER NON-LINEAR DIFFERENTIAL EQUATIONS
C
          THIS VERSION OF N-BOD2 USES
C
C
                N = 10
C
C
     MAKING USE OF N.LT.10 SAVES CONSIDERABLE COMPUTER STORAGE
C
                    N.GT.10 RUN TIME FOR PRATICAL APPLICATION EXCESSIVE
C
C
C
C
            SYMBOL LIST ABBREVIATIONS
C
      IDEM2 = N **2 + N + 1 - (N *(N-1))/2
C
      IDEM3 = (N-1)**2 + N - ((N-1)*(N-2))/2
C
      IDEM4 = SIZE OF /LOGIC/
                                  16
                                        LOGICAL WORDS
      IDEM5 = SIZE OF /INTG/
C
                                  724
                                        INTEGER WORDS
      IDEM6 = SIZE OF /INTGZ/
C
                                  70
                                        INTEGER WORDS
      IDEM7 = SIZE OF /REAL/
                                 4354 REAL WORDS
C
      IDEM8 = SIZE OF /REALZ/
C
                                 168
                                        REAL WORDS
C
      IDEM9 = SIZE OF /SATELL/ 1000 REAL WORDS
      ALL COMPUTED VECTORS AND TENSORS IN COMPUTING FRAME COORDINATES
C
C
      NA = OPTION NOT AVAILABLE IN N-BOD2
C
      # = NUMBER OF
C
      BFC = BODY FIXED COORDINATES
      CFC = COMPUTING FRAME FIXED COORDINATES (BODY 1 OR INERTIAL)
C
C
      IFC = INERTIALLY FIXED COORDINATES
C
      EQIV(XMN) = EQUIVALENCED TO XMN ARRAY
C
      O:N = BY USE OF A DUMMY VARIABLE SUBSCRIPT O ALLOWABLE
C
C
                      SYMBOL LIST AND STORAGE LOCATION
C
            TYPE DIMENSION STORAGE
C
  NAME
                                      DEFINITION AND SUBROUTINE USED IN
C
C
   ANGD
                 3(N+1)
                            EQIV(XMN) EULER ANGLE DOT (ANGLE, SETUP)
C
   AWORK
                                      LOCAL WORK AREA TO SAVE STORAGE
              I
                200
                            /INTG/
C
  CA
                           /REAL/
                                      CM VECTOR BFC (INBS)
              R
                 3 . N
                            /REAL/
                                      CM VECTOR CFC (VDIV, TRANVD)
  CAC
              R
                 3 . N
```

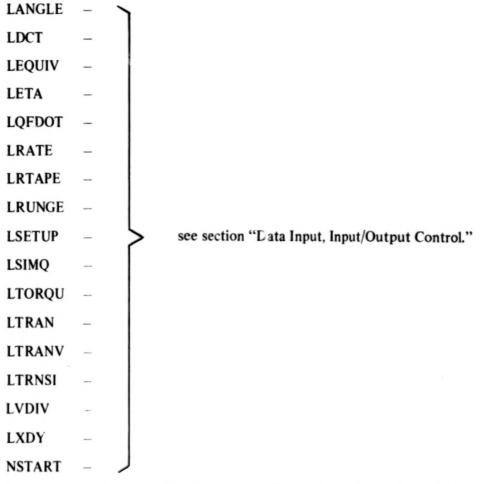
C	CAO	R	3,N	/REAL/	ZERO DEF CM VECT BFC (VDIV)
C	CBDUM, CB	R	3,0:N	/REALZ/	HINGE VECTOR BFC (INBS)
C	CBCDUM, CBC	R	3,0:N	/REALZ/	HINGE VECTOR CFC (VDIV.TRANVD)
C	CBN	R	3	/REALZ/	HINGE VECTOR PART (INBS)
C	CLM	R	N	/REAL/	SCALAR TORQUE ON WHEEL (TORQUE)
C	CNF	R	3 . N	EQIV(XMN)	FORCE CENTRIPETAL + CORIOLIS(ETA)
C	COMC	R	3,N+1	/REAL/	ANG RATE TO COMP FRAME (RATE, DCT)
C	CT1	I		/INTG/	COUNTER (INOPT) UNUSED AFTER
C	CT2	I		/INTG/	COUNTER (INOPT) UNUSED AFTER
C	CT3	1		/INTG/	COUNTER (INOPT) UNUSED AFTER
C	CT4	I		/INTG/	COUNTER (INOPT)+PASSES THRU (DYN)
C	CT5	1		/INTG/	COUNTER (INOPT) UNDSED AFTER
C	DOMC	R	3.N+1	/REAL/	PART OF ANG. ACC. VEC. (RATE)
C	DUMMY	R	1000	/SATELL/	STORAGE AREA FOR USER
C	ETC	R	3.N+1	/REAL/	GYRO+EXT. TORO. ON NEST (ETA. OFDOT)
C	ETIC	R	3.N	EQIV(XMN)	INERT X-COUP TORQ. (ETA)
C	ETM	R	33	/REAL/	SCALAR, GENEALIZED TORQUES (OFDOT)
C	ETMC	R	3.N	FQIV(XMN)	WHEEL X-COUP TORQ. (ETA)
C	FCF	R	3,3,4N	/REAL/	MODAL CENTRIP X-COUP(INOPT, QFDOT)
C	FCK	R	3,4N	/REAL/	MODAL CORIDLIS X-COUP(INOPT, OFDOT)
C	FCON	I	3(N+1)	/INTG/	CODE, FREE VECTORS (INBS)
C	FG1	L		/LOGIC/	END OF RUN FLAG (MAIN.DYN.OUTPSP)
C	FG2	L		/LOGIC/	ERROR INPUT DATA (MAIN, INEROR)
C	FG3	L		/LOGIC/	ERROR INPUT DATA(MAIN, INOPT!
C	FG4	L		/LOGIC/	UNUSED
C	FG5	L		/LOGIC/	OUTPUT DATA ? FLAG (MAIN. TORQUE)
C	FLA	R	3,2N	/REAL/	MODAL CM VECTOR BFC (INOPT)
C	FLAC	R	3,2N	/REAL/	MODAL CM VECTUR CFC (VDIV, TRANVD)
C	FLB	R	3,2N	/REAL/	MODAL MOMENT VECTOR BFC (INOPT)
C	FLC	R	3,2N	/REAL/	MODAL ROTATION MOMENT BFC (INOPT)
C	FLCRC	R	3,N	/REAL/	GYRO FLEXIBLITY FORCE (ETA)
C	FLD	R	3,3,2N	/REAL/	MODAL INERTIA DYAD BFC (INOPT)
C	FLE	R	3,3,2N	EQIV(FLD)	FLD + FLD**T (VDIV)
C	FLH	R	3,3,2N	EQIV(FLJ)	FLD + FLH (VDIV)
C	FLIRC	R	3,N	/REAL/	GYRO FLEXIBLITY TORQUE (ETA)
C	FLJ	R	3,3,2N	/REAL/	MODAL ROTATION DYAD BFC (INOPT)
C	FLO	R	3,2N	EQIV(FLB)	MODAL MOMENTUM VECTOR BFC (VDIV)
C	FLQC	R	3,2N	/REAL/	FLO IN CFC (VDIV.TRANVD)
C	FLOM	R	2N	/REAL/	MODAL FREQUENCY (INOPT)
C	FOMC	R	3,N+1	/REAL/	INERTIAL RATE VECTOR (RATE)
C	GAM	R	3, IDEM2	/REAL/	HINGE TO CM VECTOR (VDIV. XDY)
C	н	R		/REAL/	INTEGRATION STEP SIZE (RUNGE, INBS)
C	НМ	R	3,N	/REAL/	WHEEL SPIN AXIS BFC (INBS)
C	HMC	R	3.N	/REAL/	WHEEL SPIN AXIS CFC (VDIV. TRANVD)
C	HMOM	R	N	/REAL/	WHEEL ANGULAR MOMENTUM(INBS.SETUP)

C	IDEM4	I		LOCAL	SIZE OF /LOGIC/ (RSTART)
C	IDEM5	I		LOCAL	SIZE OF /INTG/ (RSTART)
C	I DEM6	I		LOCAL	SIZE OF /INTGZ/ (RSTART)
С	I DE M7	I		LOCAL	SIZE OF /REAL/ (RSTART)
C	IDEM8	1		LOCAL	SIZE OF /REALZ/ (RSTART)
C	I DE M9	I	22.2.2.2	LOCAL	SIZE OF /SATELL/(RSTART)
С	IINIT	I	IDEM5)ZERO DUT /INTG/ (RSTART)
C	INERF	L		/LOGIC/	FLAG, BFC OR IFC FOR CFC (INOPT)
C	IZINIT	I	IDEM6		M)ZERO OUT /INTGZ/ (RSTART)
C	JCON	I	N	/INTG/	BODY CONNECTION MATRIX (INBS)
C	LCON	I	2(N+1)	/INTG/	CODE, LOCKED VECTORS (INBS)
C	LANGLE	L		/LDEBUG/	PRINT EQUATIONS IN ANGLE? (MAIN)
C	LDCT	L		/LDEBUG/	PRINT EQUATIONS IN DCT? (MAIN)
C	LEOU	L		EQIV()	EQIV IN EACH SUB TO PRINT FLAG
C	LEQUIV	L		/LDEBUG/	PRINT EQUATIONS IN EQIV? (MAIN)
C	LETA	L		/LDEBUG/	PRINT EQUATIONS IN ETA? (MAIN)
C	LINIT	L	IDEM4	EQIV(FG1)	ZERO OUT /LOGIC/ (RSTART)
С	LOFDOT	L		/LDEBUG/	PRINT EQUATIONS IN OFDOT? (MAIN)
C	LRATE	L		/LDEBUG/	PRINT EQUATIONS IN RATE? (MAIN)
C	LRTAPE	Ĺ		/CHEKS/	CREATE RESTART TAPE? (MAIN)
C	LRUNGE	L		/LDEBUG/	PRINT EQUATIONS IN RUNGE? (MAIN)
C	LSETUP	Ĺ		/LDEBUG/	PRINT EQUATIONS IN SETUP? (MAIN)
Č	LSIMO	ī		/LDEBUG/	PRINT EQUATIONS IN SIMO? (MAIN)
Č	LTORQU	ũ		/LDEBUG/	PRINT EQUATIONS IN TORQUE? (MAIN)
Č	LTRAN	ī		/LDEBUG/	PRINT EQUATIONS IN TRAN? (MAIN)
Č	LTRANV	ĭ		/LDEBUG/	PRINT EQUATIONS IN TRANVO? (MAIN)
Č	LTRNSI	ĭ		/LDEBUG/	PRINT EQUATIONS IN TRNSIV? (MAIN)
č	LVDIV	ĭ		/LDEBUG/	PRINT EQUATIONS IN VDIV? (MAIN)
č	LXDY	i		/LDEBUG/	PRINT EQUATIONS IN XDY? (MAIN)
c					The state of the s
	MO	I	N	/INTG/	BODY IN WHICH WHEEL IS IN (INBS)
C	NBOD	i		/INTG/	NUMBER OF BODIES (INBS)
C	NB1	I		/INTG/	NUMBER OF BODIES + 1 (INBS)
C	NCTC	1		/INTG/	(INOPT.NA) CONSTRAINT TORQUES
C	NEO	I		LOCAL	# EQUATIONS SETUP BY N-BOD2 (EQIV)
C	NFER	1		/INTG/	# FREE COORD VECTORS (INBS)
C	NFKC	I		/INTG/	(INOPT, NA) CONSTRAINT FORCES
C	NFLXB	1		/INTG/	# FLEXIBLE BODIES (INOPT)
C	NFRC	1		/INTG/	# RELATIVE ANGLES COMPUTED (INOPT)
C	NLOR	I		/INTG/	# LOCKED COORD VECTORS(INBS)
C	NMO	I		/INTG/	TOTAL NUMBER OF WHEELS (INBS)
C	MOA	1		/INTG/	# WHEELS TO COMP REL ANGLE (INOPT)
C	NMCDS	I		/INTG/	TOTAL # MODES FOR SYSTEM (INSPT)
C	NMV	1		/INTG/	# VARIABLE SPEED WHEELS (INOPT)
C	NSTART	L		/CHEKS/	NEW OR RESTART RUN? (MAIN)
C	NSVP	1		/INTG/	# LOCKED VECTORS TRANSFORM(VDIV)

-	*****				
C	NSVO	I		/INTG/	# FREE VECTORS TRANSFORM (VDIV)
C	NTO	I		/INTG/	# DIFF EQS.IN SUB TORQUE (TORQUE)
C	PCON	I	N+1	/INTG/	# CONSTRAINED AXES AT HINGES(INBS)
C	PHI	R	3,N+1	/REAL/	EXTERNAL TORQUE ON NEST (TORQUE)
C	PLM	R	N	/REAL/	WHEEL SPIN INERTIA (INBS)
C	QF	R	3,3(N+1)	/REAL/	FREE VECTOR BFC (INBS)
C	QFC	R	3,3(N+1)	/REAL/	FREE VECTOR CFC (VDIV, TRANVD)
C	QL	R	3,2(N+1)	/REAL/	LOCKED VECTOR BFC (INBS)
C	OLC	R	3,2(N+1)	/REAL/	LOCKED VECTOR CFC (VDIV, TRANVD)
C	RBLO	L	N	/LOGIC/	RIGID BODY OR POINT MASS? (INBS)
С	RINIT	R	IDEM7	EQIV(CA)	ZERO OUT /REAL/ (RSTART)
C	ROMC	R	3,N+1	/REAL/	RELATIVE RATE VECTOR (RATE)
C	RZINIT	R	IDEM8		ZERO OUT /REALZ/ (RSTART)
C	SC	I	3(N+1)	/INTG/	FREE VECTORS CAGED (INOPT, UNCAGE)
C	SCC	I	N	/INTG/	UNUSED
C	SCG	I	-1-2-2	/INTG/	# CAGED DEGREES (INOPT, UNCAGE)
C	SCNDUM, SCN		0:N-1	/INTGZ/	CODE, CENTRIPETAL EFFECTS (INOPT)
C	SCRDUM, SCR		0:N-1	/INTGZ/	CODE, CORIOLIS EFFECTS (INOPT)
C	SCXC	I	2N	EQIV(TORQ)	
C	SD	I		/INTG/	CODE, DIRECTION COSINES (INOPT)
C	SEU	Ĭ		/INTG/	CODE, EULER ANGLES (INOPT)
C	SFCC	I		/INTG/	CODE. BODIES FLEX X-COUPLING (INOPT
C	SFK DUM, SFK	I	0:N-1	/INTGZ/	CODE, CONSTRAINT FORCE (INOPT, NA)
C	SFLX	I		/INTG/	CODE, ALL FLEXIBLE BODIES (INOPT)
C	SFR	I	3(N+1)	/INTG/	CODE.COMPUTE FREE VEC ANGLE (INOPT)
C	SFXM	I	N	/INTG/	# MODES EACH BODY (INOPT)
C	SG	I		/INTG/	CODE, ALL GYROSTATS (SETS)
C	SI	I	IDEM3	/INTG/	CODE, BODIES HINGE TO CM (SETS)
C	SIG	I		/INTG/	UNUSED
C	SIXDUM, SIX	I	0:N-1	/INTGZ/	CODE, INERTIA EFFECTS (INOPT)
C	SKDUM, SK	I	0:N-1	/INTGZ/	CODE, BODIES IN EACH NEST (SETS)
C	SL	I		/INTG/	CODE, ALL POINT MASSES (SETS)
C	SLK	I	3(N+1)	/INTG/	CODE, CONSTRAINT TORQUE(INOPT, NA)
C	SMA	1	N	/INTG/	CODE, WHEEL ANGLE COMPUTE(INOPT)
C	SMAL	I		/INTG/	CODE, SMALL ANGLES (INOPT)
C	SMCDUM, SMC	1	0:N-1	/INTGZ/	CODE, ALL WHEELS IN NEST (INOPT)
C	SMV	I		/INTG/	CODE, VARIABLE SPEED WHEELS (INOPT)
C	SOK	I	N+1	/INTG/	CODE, BODIES HINGE O - CM (VDIV)
C	SPIDUM, SPI	-	0:N-1	/INTGZ/	CODE, PSUEDO INERTIA TENSORS (INOPT)
C	SOF	I	N+1	/INTG/	CODE. FREE VECTOR AT HINGE (SETS)
C	SOL	I	N+1	/INTG/	CODE.LOCKED VECTOR AT HINGE (SETS)
C	SR	I		/INTG/	CODE, ALL RIGID BODIES (SETS)
С	SSCN	1		/INTG/	CODE, UNION OF ALL SCN (VDIV)
C	221X	I		/INTG/	CODE, UNION OF ALL SIX (VDIV)
C	SVA	I		/INTG/	CODE, CM VECTORS TRANSFORM (VDIV)

-	CHD			ATAITC A	CODE WINCE MECTODE TOWNSEDDMINDING
C	SVB	1		/INTG/	CODE, HINGE VECTORS TRANSFORM(VDIV)
C	SVD	1		/INTG/	CODE, DON'T TRANSFORM (INQPT)
C	SVI	1		/INTG/	CODE, INERTIA DYAD TRANSFORM (VDIV)
C	SVM	I		/INTG/	CODE, SPIN VECTORS TRANSFORM(VDIV)
C	SVP	I	2(N+1)	/INTG/	CODE, LOCKED VECTORS TRANSFORM(VDIV
C	SVQ	I	3(N+1)	/INTG/	CODE, FREE VECTORS TRANFORM(VDIV)
C	SXM	I	3 • N	/INTG/	CODE, SMALL ANGLE KINEMATICS (INOPT)
C	SXT	I		/INTG/	CODE, TIME VARY COL INER MAT(INOPT)
C	T	R		/REAL/	TIME (MAIN)
C	TEM	R	2,160	LOCAL	TEMP STORAGE AREA (RUNGE)
C	THA	R	33	/REAL/	GENEALIZED COORDINATES(INBS, SETUP)
C	THAD	R	33	/REAL/	GENERALIZE COORD RATE (INBS, SETUP)
C	THADD	R	33	EQIV(ETM)	GENERALIZE COORD ACC (SETUP, SIMO)
C	THADW	R	N	/REAL/	WHEEL RATE (INBS. SETUP)
C	THAW	R	N	/REAL/	WHEEL ANGLE (INBS.SETUP)
C	TIMEND	R		/REAL/	TIME TO END RUN (INBS.DYN)
C	TORQ	I	97	/INTG/	UNUSED STORAGE AREA FOR USER
C	TUG	R	3(N+1)	/REAL/	TIME TO UNCAGE (INOPT, UNCAGE)
C	XDIC	R	3,3,1DEM2	/REAL/	MATRIX OF INERTIA TENSORS(VDIV, XDY
C	ΧI	R	3,3,N	/REAL/	INERTIA DYAD BFC (INBS)
C	XIC	R	3,3,N	/REAL/	INFRIIA DYAD CFC (VDIV.TRANVD)
C	x10	R	3,3,N	/REAL/	ZERO INERTIA DYAD BFC(VDIV)
C	XMAS	R	N	/REAL/	BODY MASS (INBS)
C	XMC DUM . XMC	R	3,3,0:N	/REALZ/	TRANSFORM BEC TO CEC (TRNSIV, TRAN)
C	XMN	R	33,33	/REAL/	SCALAR INERTIA MATRIX (VDIV.QFDOT)
C	Y	R	160	LOCAL	SYSTEM STATE (EQIV. SETUP. TORQUE)
C	Y D	R	160	LOCAL	SYSTEM STATE DERIV (SETUP, TORQUE)
C	YMCD	R	3,2,N+1	EQIV(XMN)	DIRECTION COSINE RATES (DCT)
C	XMT	R	3,3,N	/REAL/	ZERO STATE TRANSFORMTION MAT(INBS)
C	ZETA	R	2N	/REAL/	MODAL DAMPING RATIO (INOPT)
C					
C					

- FG2 input error flag. If .TRUE., the input data defines a physically realizable system. If .FALSE., a criteria for physical realizability in subroutine INEROR has not been satisfied and the job will terminate with an error message.
- FG3 input error flag. If .FALSE., a code word on an option card read by subroutine INOPT has not been recognized and the job will terminate with an error message.
- FG5 output data flag. Its status is checked at the end of each integration step. If .TRUE., a call to the data output subroutine OUTPSP is made. If .FALSE., it is not. To change the frequency of data output, the user may change the status of FG5 in subroutine TORQUE. The default status of FG5 is .TRUE..



- T independent variable, defines actual simulation time. Evaluated in subroutine RUNGE.
- TIMEND termination time. At T.GE.TIMEND, the flag FG1 is reset to .FALSE. in subroutine DYN.

For additional discussion, see comment cards inserted into the MAIN program and subroutine DYN.

DATA INPUT, INPUT/OUTPUT CONTROL

The first card of the data deck is called from the MAIN program by the statement:

READ 102, NSTART, LRUNGE, LTRNSI, LVDIV, LEQUIV, LTRAN, LTRANV, LRATE, LXDY LETA, LTORQU, LQFDOT, LDCT, LANGLE, LSETUP, LSIMQ, LRTAPE

102 FORMAT (4X, 17L1)

The data on the card set 17 logic flags that are used to control the mode of input and output. The following definitions apply to the logic variables set by the data on this card:

The first logic variable controls the mode of data input.

NSTART = .FALSE. A new job: data input will be from cards. The starting time for the simulation run will be time zero (T.EQ.0).

= .TRUE. A restart job: data input will be from tape. The input tape for a restart job is the output tape of a previous job. It is generated by N-BOD2. The starting time for the simulation will be the termination time of the job for which the restart tape was written.

The next 15 logic variables control the print commands programmed in the various subroutines. For example:

LRUNGE = .FALSE. All print statements coded in subroutines RUNGE will be bypassed.

= .TRUE. All equations coded in subroutine RUNGE will be printed along with the numerical magnitudes of the associated variables at the time of execution.

Table 2 lists the subroutines in which the system equations of motion are coded and the associated logic variables that control whether or not the equations coded therein should be outputted on the line printer.

The last logic variable of card 1 controls whether or not a restart tape should be written.

LRTAPE = .FALSE. Create a restart tape at the termination time of this job.

= .TRUE. Do not create a restart tape at the termination time.

If a restart tape is created, the restart data are put into file 2 of the output tape referred to as data set 11 by the WRITE statements.

DATA INPUT, SUBROUTINE RSTART

After the first data card is read, a CALL to subroutine RSTART is made. The precautionary step of zeroing all storage locations, except those already loaded by the data on the first input

Table 2

Logic Variables Controlling the Printing of the Equations of Motion Coded in the Subroutines

Logic Variable	Subroutine
LRUNGE	RUNGE
LTRNSI	TRNSIV
LVDIV	VDIV
LEQUIV	EQIV
LTRAN	TRAN
LTRANV	TRANVD
LRATE	RATE
LXDY	XDY
LETA	ETA
LTORQU	TORQUE
LQFDOT	QFDOT
LDCT	DCT
LANGLE	ANGLE
LSETUP	SETUP
LSIMQ	SIMQ

card, is performed upon entry. A check on the status of the logic variable NSTART is then made:

IF (NSTART .EQ. FALSE),

a return to the main program is immediately made. The data to be read in will be from cards and will define a new job.

IF (NSTART .EQ. TRUE),

the data to restart an old job will be read according to the read statements coded in subroutine RSTART. The restart tape is read according to the following statements:

READ (10, 102) Y

READ (10, 102) YD

READ (10, 101) NEQ

READ (10, 102) (DUMMY (I), I = 1, IDEM9)

READ (10, 102) (RINIT (I), I = 1, IDEM7)

READ (10, 102) (RZINIT (I), I = 1, IDEM8)

READ (10, 101) (IINIT (I), I = 1, IDEM5)

READ (10, 101) (IZINIT (I), I = 1, IDEM6)

READ (10, 101) (LINIT (I), I = 1, IDEM4)

101 FORMAT (16 Z 8)

102 FORMAT (8 Z 16)

These statements read the restart tape exactly as it was written. The user has no control over the writing or reading of the restart tape other than by the logic control variable LRTAPE that defines whether or not it should be created at the time of run termination.

At the end of any job that calls for a restart tape to be generated, the restart data are put in file 2 of the output tape which is data set 11. To execute a restart job, the program assumes that the appropriate job control statements have been provided that will position the restart tape (now data set 10) at the start of file 2 before the execution of the first READ input tape instruction. (See the comment cards in subroutine RSTART and the job control requirements discussion in the following section.)

After the restart tape has been read, the last input card required for a restart run is read by the statement:

READ 103, TIMEND 103 FORMAT (D15.5)

in RSTART where

TIMEND = termination time for present job.

This read statement is executed only on a restart job. Upon exit from RSTART, return is made to the start of the numerical integration loop in the MAIN program. The job then proceeds as if it had never been previously terminated. There are no more data input cards required for a restart job.

PROGRAMMER'S GUIDE TO SUBROUTINE RSTART

There is no actual computation carried out in subroutine RSTART. Its functions are:

- Zero all storage locations used by N-BOD2 before any computation is done.
- Read the restart tape so that computation may be reinitiated at the termination time of a previous run.
- Write the restart tape so that computation may be restarted at a later data.

For further detail, see the comment cards inserted in the subroutine RSTART.

To zero out all common blocks, the size of each must be defined. Thus:

IDEM4 = number of logical words in /LOGIC/

IDEM5 = number of integer words in /INTG/

IDEM6 = number of integer words in /INTGZ/

IDEM7 = number of real words in /REAL/

IDEM8 = number of real words in /REALZ/

IDEM9 = number of real words in /DUMMY/

These parameters are defined in subroutine RSTART and must be changed if any of the primary labeled common blocks are extended or modified. The user is referred to the program listing to note the method used to zero the common blocks.

To make use of the restart capability, the user is required to provide appropriate machinedependent job control statements.

N-BOD2 is programmed to put all user-desired output data in file 1 of data set 11 and to put all of the restart data in file 2 of data set 11. Data set 11 becomes the restart tape.

To restart the job, the restart tape becomes data set 10. The appropriate job control statements must be provided to position it at the start of file 2 prior to the execution of the first read tape instruction of the program.

For a restart job, the author has found it convenient to provide the job control statements that copy, prior to job execution, file 1 of data set 10 onto file 1 of data set 11. Data set 10 will then be positioned at the start of file 2 and, at the end of the restart job, file 1 of data set 11 will contain a continuous record of the output data from time zero. Furthermore, the old restart tape, data set 10, will not have been destroyed.

DATA INPUT, SUBROUTINE INBS

IF (NSTART .EQ. FALSE)*,

a call to the subroutine INBS is made immediately after the program returns to the MA'N program from RSTART. In INBS, the input data required to describe the basic simulation model are read in from cards.

As in References 1 and 2, the labeling of a system of N bodies (rigid bodies + flexible bodies + point masses) and M symmetric wheels must adhere to the following rules:

Bodies must be given distinct integer labels ranging from 1 to N inclusive. The
labeling must be such that, along any topological path extending from body 1 to
a limb end, the body labels are of increasing magnitude.

^{*}Condition code for a new job.

- Symmetric wheels must be given distinct integer labels ranging from 1 to M inclusive. These may be randomly assigned.
- Body 1 is treated as the principal body of the system.

The labeling of hinge points between contiguous bodies is done by the computer according to the following rule:

 Hinge point K-1 is the point of connection between body K and the chain of bodies extending to it from body 1.

Figures 3 and 4 are provided as visualization aids. Figure 3 is the example used in Reference 1 to illustrate the defined labeling convention. Figure 4 shows the exact position and labeling of each of the position vectors defined for the system.

The following definitions are used in the coding of subroutine INBS. The total number of bodies and wheels that make up the simulation model are defined by:

NBOD - total number of rigid bodies, flexible bodies, and point masses

NMO - total number of symmetric wheels

also defined is the constant

$$NB1 = NBOD + 1$$

As a direct consequence of the established labeling convention, the system topology can be uniquely defined by the one dimensional arrays:

JCON(K) for $K = 2,3,, NBOD$	Body label of the body connected to body K at hinge point K-1. Relative to body 1, it is the body inboard of body K.
JCON(1) = 0	implies body 1 is contiguous to the inertial frame of reference.
$MO(M)$ for $M = 1, 2, \dots, NMO$	Body label of the body in which symmetric wheel M is is imbedded.

The physical nature of each body, its mass and the number of kinematic constraints between contiguous bodies, are defined by:

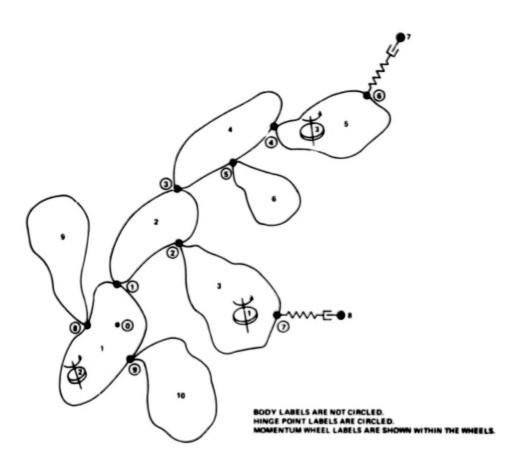


Figure 3. Labeling scheme for 10-body example.

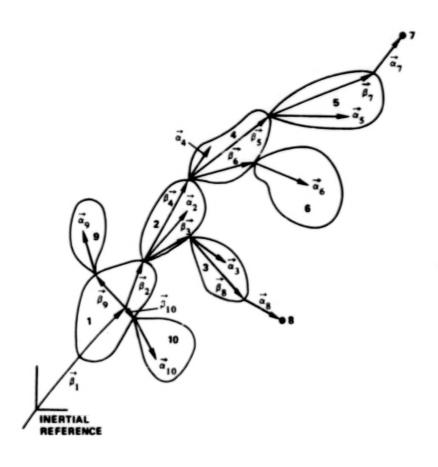


Figure 4. Positions and labeling of hinge-point and center-of-mass location vectors.

PCON(K)	Notes the state of
for K = 1	Number of kinematically constrained rotational degrees of freedom between body 1 and an inertially fixed frame
	of reference.
for $K = 2,3,\ldots,NBOD$	Number of kinematically constrained rotational or trans-
	lational degrees of freedom between body K and body
	JCON(K).
for $K = NBOD+1$	Number of kinematically constrained translational degrees
	of freedom between body 1 and the inertially fixed frame of reference.
	0 implies 3 degrees of relative freedom
DCON(V)	0 implies 3 degrees of relative freedom

The equations of motion have been derived in a vector-dyadic format and are valid for all frames of reference. To numerically solve these equations, it must be possible to express any vector or tensor relative to any desirable frame of reference.

The equations of motion are derived relative to an origin that is fixed in an inertially fixed-reference system. The user is required to pick an inertial origin and to define an orthogonal reference frame there. All translational and rotational motion of body 1 is computed relative to this inertially fixed-reference frame.

Let

$$(X_0, Y_0, Z_0)$$
 = coordinate axes of the inertially fixed-reference frame
N-BOD2 assumes that if:

PCON (NBOD + 1) = 0 Body 1 unconstrained in translation

PCON (NBOD + 1) = 1 Body 1 constrained to translate in the
$$X_0$$
, Y_0 plane

PCON (NBOD + 1) = 2 Body 1 constrained to translate in the X_0 direction

PCON (NBOD + 1) = 3 Body 1 totally constrained in translation

In addition to the inertial reference frame, body fixed-reference frames must also be defined. Consequently, a body K fixed-reference frame is defined at hinge point K-1; $K=1,2,\ldots$ NBOD. The orientation of the body K fixed-coordinate axes is arbitrary and to be defined by the user. To simplify the input of initial kinematic conditions, it is desirable to define a zero state for the system. All relative motion between contiguous bodies can then be measured relative to this state in terms of a few physically meaningful relative displacement parameters.

The following set of transformation matrices completely defines the relative orientation of all reference frames when the system is in the zero relative displacement state.

$$[XMT (1,1,K)] = \begin{bmatrix} XMT (1,1,K) & XMT (1,2,K) & XMT (1,3,K) \\ XMT (2,1,K) & XMT (2,2,K) & XMT (2,3,K) \\ XMT (3,1,K) & XMT (3,2,K) & XMT (3,3,K) \end{bmatrix}$$

where

$$K = 1, 2, \dots, NBOD$$

If K = 1, the inputted transformation matrix transforms vectors from body 1 fixed coordinates to inertial fixed coordinates.

The origin of the body K fixed-reference frame is always at hinge point K-1; K = 1, 2, ..., NBOD. If body K, K = 2, 3, ..., NBOD, is a point mass, a transformation matrix is not inputted. The axes of the body fixed-reference frames are defined by the computer to be respectively parallel to the axes of the body JCON(K) fixed-reference frame.

The components of all inertia tensors and position vectors required to describe the physical size and rotational inertia characteristics of the simulation model are inputted relative to the body fixed-reference frame in which they are fixed. That is:

 components of the inertia tensor for body K and all despun wheels contained therein about the body's center of mass, relative to the body K fixed-reference frame (assumed to be zero if body K is a point mass).

$$[XI(1,1,K)] = \begin{bmatrix} XI(1,1,K) & XI(1,2,K) & XI(1,3,K) \\ XI(2,1,K) & XI(2,2,K) & XI(2,3,K) \\ XI(3,1,K) & XI(3,2,K) & XI(3,3,K) \end{bmatrix}$$

$$CA(I, K)$$
 - for $K = 1, 2, ..., NBOD$

 components of the vector from hinge point K-1 to the center of mass of body K (zero state location if body K is a point mass), relative to the body K fixed-reference frame.

$${CA(1,K)} = \begin{cases} CA(1,K) \\ CA(2,K) \\ CA(3,K) \end{cases}$$

$$CB (I, K)$$
for $K = 0$

- reserved for the components of the vector from the inertial origin to the composite system center of mass. (Not needed for computation and hence not computed, may be user-defined if desirable.)

for K = 1, 2, ..., NBOD — components of the vector from hinge point JCON(K)-1to hinge point K-1, (from inertial origin if K = 1), relative to the body JCON(K) fixed-reference frame

$$\left\{ CB(i,K) \right\} = \left\{ \begin{array}{l} CB(1,K) \\ CB(2,K) \\ CB(3,K) \end{array} \right\}$$

Note: Special provision has been made in the coding of N-BOD2 to accept the subscript 0 in certain arrays such as CB. Furthermore, to avoid numerical computation problems, it is advisable to avoid placing the inertial origin at a distance that is many orders of magnitude greater than the diameter of a sphere which could contain the entire simulation model.

The previously defined integer array PCON(K), K = 1, ..., NBOD+1, specifies the number of kinematic constraints that exist between contiguous bodies and between body 1 and the inertial reference. The logical array RBLO(K), K = 1, 2, ..., NBOD, can be used to determine whether relative motion between the bodies K and JCON(K) is rotational or translational. Body 1 may have both rotational and translational degrees of freedom relative to the inertial reference. Rigid and flexible bodies may have only relative rotational degrees of freedom while point masses may have only relative translational degrees of freedom. N-BOD2 assumes that relative rotational motion may be adequately modeled by either a 0-, 1-, 2-, or 3-degree-offreedom gimbal, while relative translational motion may be either 0, 1, 2, or 3 dimensional. Both the directions about which, or along which, motion is free of kinematic constraints and the directions about which, or along which, motion is kinematically constrained must be defined.

These directions are defined by a set of exactly NBOD+1 triads of unit coordinate vectors. These coordinate vectors are defined to be either free coordinate vectors (implying that motion is free about or along the directions defined by them) or locked coordinate vectors (implying that motion is locked or kinematically constrained about or along the directions defined by them). The user will be required to define two of the three coordinate vectors; the third will be internally generated by a vector cross product based upon conditions of orthogonality.

The integer array PCON(K), K = 1, 2, ..., NBOD+1, defines the mix of free and locked coordinate vectors in each of the NBOD+1 triads. It also provides a convenient tool for creating a labeling sequence for the free and locked coordinate vectors. The labeling will be done by the computer.

It is a sequential numbering algorithm that starts with the coordinate vectors associated with relative rotational motion of body 1, proceeds sequentially up to body NBOD, and ends with the coordinate vectors associated with the description of the translational motion of body 1.

Let

{QF (I, M)} = components of the unit free coordinate vector M relative to the reference frame in which it is fixed.

{QL (I, L)} = components of the unit locked coordinate vector L relative to the reference frame in which it is fixed.

The mix of free and locked coordinate vectors at hinge point K-1 and their labeling sequence are defined as follows for K = 1, 2, ..., NBOD+1:

- For PCON (K) = 0 the mix of coordinate vectors at hinge point K-1 is $\{QF(I, M)\}, \{QF(I, M+1)\}, \{QF(I, M+2)\}$
- For PCON (K) = 1 the mix of coordinate vectors at hinge point K-1 is $\{QF(I, M)\}, \{QF(I, M+1)\}, \{QL(I, L)\}.$
- For PCON (K) = 2 the mix of coordinate vectors at hinge point K-1 is
 {QF (I, M)}, {QL (I, L)}, {QL (I, L + 1)}.
- For PCON (K) = 3 the mix of coordinate vectors at hinge point K-1 is
 {QL (I, L)}, {QL (I, L + 1)}, {QL (I, L + 2)}

where for any K = 1, 2, ..., NBOD + 1

$$M = 1 + \sum_{\substack{i=1 \ K \neq 1}}^{K-1} (3 - PCON(i))$$

$$L = 1 + \sum_{\substack{i=1 \ K \neq i}}^{K-1} PCON(i)$$

One of several different kinematic conditions can exist at each hinge point. The user must adhere to the following rules when specifying the coordinate of the free and locked coordinate vectors in each of the NBOD+1 triads:

If RBLO (K) = .TRUE. for any K = 1, 2, ..., NBOD, the coordinate vectors are
associated with gimbal axes. Table 3 defines for this case the coordinate frames
in which the free and locked coordinate vectors are defined.

- If RBLO (K) = .FALSE. for any K = 2, 3, ..., NBOD, the coordinate vectors define the directions along which relative translational motion of point mass K is free and along which it is constrained. The origin of this triad of coordinate vectors is the zero position of the point mass K that is defined by the components of the center of mass vector {CA (I, K)}. Table 4 defines the coordinate frame in which the free and locked coordinate vectors are defined.
- If K = NBOD+1, the coordinate vectors define the direction along which the center of mass of body 1 is free to translate. These directions are defined by the computer based upon the number of kinematic constraints defined by PCON(NBOD+1). Table 5 defines the coordinates of the unit coordinate vectors relative to the inertially fixed reference. These are set by the computer.

The initial state of the simulation model can now be defined by specification of initial displacements and rates about or along the free coordinate vectors whose direction defines the directions of positive displacement. Let

THA (M) = initial relative displacement about or along the free coordinate vector M

THAD (M) = initial relative rate about or along the free coordinate vector M

The user need not be concerned with defining initial values for transformation matrices since it is done by an internal computer computation.

Table 3

Coordinate Frames in Which Free and Locked Coordinate Vectors are to be Defined for RBLO (K) = .TRUE.; K = 1, 2, ..., NBOD

Vector	PCON (K)					
vector	0	1	2	3		
{QF (I, M)}	JCON (K)	JCON (K)	JCON (K)			
$\{QF(I, M+1)\}$	Intermediate	К				
$\{QF(I, M+2)\}$	К					
{QL (I, L)}		Intermediate	к	K		
${QL(I, L+1)}$			К	K		
$\{QL(I, L+2)\}$				K		

Table 4

Coordinate Frames in Which Free and Locked
Coordinate Vectors are to be Defined for

RBLO (K) = .FALSE.; K = 2, 3, ..., NBOD

Vector	PCON (K)					
	0	1	2	3		
{QF (1, M)}	K	K	K			
$\left\{ QF\left(1,M+1\right) \right\}$	К	K				
${QF(1, M+2)}$	K					
{QL (1, L)}		K	К	K		
${QL(1,L+1)}$			K	К		
$\left\{ QL\left(1,L+2\right) \right\}$				K		

Table 5
Coordinates of the Unit Coordinate Vectors Defined at the Inertial Origin Along Which Translational
Motion of Body 1 is Measured;

K = NBOD + 1

Vector	PCON (K)			
	0	1	2	3
{QF (I, M)}	L 1, 0, 0 J	L 1,0,0 J	L 1, 0, 0 J	
${QF(I, M+1)}$	L 0, 1, 0 J	L 0, 1, 0 J		
${QF(I, M+2)}$	L 0, 0, 1 J		e i	
{QL (I, L)}		L 0, 0, 1 J	L 0, 1, 0 J	L 1, 0, 0 J
{QL (I, L + 1)}			L 0, 0, 1 J	L 0, 1, 0 J
{QL (I, L + 1)}				L 0, 0, 1 J

To define the characteristics of each of the symmetric wheels imbedded within the simulation model, the following definitions are made:

{HM (I, M)} - components of a unit vector along the spin axis of symmetric wheel
 M relative to the body MO(M) fixed-reference frame. Its direction
 defines the direction of positive rotation.

PLM (M) - rotational inertia of the symmetric wheel M about its spin axis.

THAW (M) - initial angular position of the wheel M about its spin axis.

THADW (M) — initial angular rate of the wheel M about its spin axis relative to body MO(M).

The integration step size for the fourth order Runge-Kutta integration package and the time for job termination are defined by:

H – integration step size

TIMEND – job termination time

To completely specify the initial state of the simulation model, the above parameters must be defined by the user or be internally generated. The following is a listing of the READ statements coded in subroutine INBS in order of execution. The data deck must be prepared accordingly.

```
******* READ STATEMENTS FOR SUBROUTINE INBS IN ORDER OF EXECUTION *********
       INITIALIZE FREE AND LOCKED COORDINATE VECTOR LAHELS
       M = 1
****** FIRST CARD HEAD BY INHS IS SECOND CARD OF DATA DECK
       READ 100. NEOD
******* READ EXACTLY NBOD SETS OF BODY DATA. THE PER HODY
      DO 1 K=1.NBOD
READ 105, N. (MESS(J).J=1.18)
       TE(N. NE.K.) ERROR. CARD OUT OF SEQUENCE, PRINT MESSAGE, HALT
MESS(J), J=1.18 ALPANUMERIC DESCRIPTION OF HODY N. PRINTED WITH DATA ECRU
C
       READ 101, RALDIKI, JCONIKI, PCONIKI, XMASIKI
       IFIRHLOIKI) GO TO 2 HODY K IS A HIGID OR FLEXIBLE HODY
       GO TO A BODY K IS A POINT MASS
     2 READ 102. ((XI(I,J,K),J=1.3).[=1.3)
    READ 102. ((xMT([,J,K),J=1,3),[=1,3)

# READ 102. (CA(J,K),J=1,3)

READ 102. (CH(J,K),J=1,3)
      COMPUTE LABELS FOR FREE AND LOCKED COORDINATE VECTORS INTERNALLY
       IF(K.E0.1) GO TO 12
       M = M + 3 - PCON(K-1)
       L = L + PCONIK-11
   12 GO TO (13.14.15.17) PCON(K)+1
                      THREE DEGREES OF RELATIVE FREEDOM FOR HODY K
   13 CONTINUE
       READ 102. (QF(J.M), J=1.3)
      READ 102, (OF(J.M+2),J=1,3)
READ 102, (THA(J),J=M.M+2)
READ 102, (THAD(J),J=M.M+2)
   GO TO 1 END OF DATA FOR BODY K
14 CONTINUE TWO DEGREES OF REL
                      TWO DEGREES OF RELATIVE FREEDOM FOR HODY K
       READ 102. (OF(J.M).J=1.31
       READ 102. (OF(J.M+1).J=1.3)
       READ 102. (THA(J).J=M.M+1)
      READ 102. (THAD(J).J=M.M+1)
GO TO 1 END OF DATA FOR BODY K
```

```
15 CONTINUE
                    ONE DEGREE OF RELATIVE FREEDOM FOR HODY K
      READ 102, (OF(J,M),J=1,3)
     READ 102, (QL(J,L),J=1,3)
READ 102, THA(M)
  READ 102, THAD(H)
GO TO 1 END OF DATA FOR HODY K
17 CONTINUE ZERO DEGREES OF RE
                    ZENO DEGREES OF RELATIVE FREEDOM FOR BODY K
      READ 102, (QL(J,L),J=1,3)
      READ 102. (OL(J.(+1).J=1.3)
     GO TO 1 END OF DATA FOR HOLY K
    1 CONTINUE
SECURE ALL HODY DESCRIPTIVE DATA IS IN MEMORY NOW
SESSESSES READ THANSLATION CONDITIONS FOR HIDY 1
      READ 100. PCON(NBOD+1)
M = M + 3 - PCON(NBOD)
      READ 102. (THAD(.)). J=M.M. 2-PC (N(MHOD+1))
DESCRIPTION OF ALL SYMMETRIC WHEEL DATA
      READ 100. NHO
      DO 16 1=1.NMO
                        GO TO 16 IF NMO. ED. O
      READ 104. MU(1).(HM(J.I).J=1.3)
      READ 106, PLM(1), (MESS(J), J=1.16)
      READ 102. THAN(1).THADW(1)
  16 CONTINUE
SESSESSES ALL WHEEL DATA IS IN MEMORY
...... HEAD STEP SIZE AND TIME TO FAID SIMULATION
      READ 102. H. TIMEND
      FND OF DATA TO HE HEAD BY SUBRIDITINE INBS
BRADGERORE FORMAT STATEMENTS USED
 100 FORMAT (15)
  101 : ORMAT (L5.215.015.5)
  102 FORMAT (3015.5)
  104 FORMAT (15.3015.51
 105 FORMAT (15.1844)
  106 FORMAT (D15.5.16A4)
```

PROGRAMMER'S GUIDE TO SUBROUTINE INBS

The primary function of subroutine INBS is to read the data cards that define the basic simulation model and its initial kinematic conditions. This has been thoroughly discussed in the section "Data Input, Subroutine INBS." A cursory glance at the subroutine listing will show that it is also programmed to provide an echo of the input data and to compute a few additional variables that will be needed for the succeeding computations.

The following variables defined in table 1 are either first introduced or used extensively in subroutine INBS. The programmer is referred to the comment cards inserted therein and the following for detailed definitions:

```
CA (I, K) - see section "Data Input, Subroutine INBS."
CB (I, K) - see section "Data Input, Subroutine INBS."
          - computed variable. Used to compute body 1 center of mass location
CBN(I)
            relative to inertial origin
```

if PCON(NB1) = 0

$$= \begin{cases} 0 \\ 0 \\ CB(3,1) \end{cases}$$
 if PCON (NB1) = 1
$$= \begin{cases} 0 \\ CB(2,1) \\ CB(3,1) \end{cases}$$
 if PCON (NB1) = 2
$$= \begin{cases} CB(1,1) \\ CB(2,1) \\ CB(3,1) \end{cases}$$
 if PCON (NB1) = 3

FCON (M) - code used to define the body label of the body in which free coordinate vector M is fixed.

FCON (M) = K if free coordinate vector M is fixed in body K

FCON (M) = -(M-1) if free coordinate vector M is the intermediate axis of a three axis gimbal

H - see section "Data Input, Subroutine INBS."

{HM (I, M)} - see section "Data Input, Subroutine INBS."

HMOM (M) - relative angular momentum of momentum wheel M

HMOM(M) = PLM(M) * THADW(M)

JCON (K) - see section "Data Input, Subroutine INBS."

LCON (L) — code used to define the body label of the body in which locked coordinate ordinate vector L is fixed

LCON (L) = K if locked coordinate vector L is fixed in body K

= -M if locked coordinate vector L is the axis about which relative motion is kinematically constrained on a two axis gimbal defined by the free vector M and M+1

MO (M) - NBOD - see section "Data Input, Subroutine INBS."

NFER - total number of free coordinate vectors

NLOR - total number of locked coordinate vectors

NMO –
PCON (K) –
see section "Data Input, Subroutine INBS."
PLM (M) –

```
{QF (I, M)} - 

{QL (I, L)} - 

RBLO (K) - 

THA (M) - 

THAD (M) - 

THAW (M) - 

THADW (M) - 

TIMEND - 

[XI (I, J, K)] - 

XMAS (K) - 

[XMT (I, J, K)] -
```

PROGRAMMER'S GUIDE TO SUBROUTINE INEROR

The main function of subroutine INEROR is to check the data inputted by subroutine INBS for obvious errors.

The following error checks are made:

- All bodies must have positive mass greater than zero.
- The topological tree must be properly labeled; i.e., JCON (K) must be less than K for all K where K = 1, 2 ..., NBOD.
- The number of kinematic constraints must be 0, 1, 2, or 3.
- Inertia tensors must be symmetric and have a positive nonzero determinant.
- Zero-state transformation matrices must be orthonormal.

If any of the above tests are not satisfied, the flag FG2 is set .FALSE.. Appropriate error messages are printed to assist the user in locating the error source, and the job will terminate after a return to the MAIN program.

PROGRAMMER'S GUIDE TO SUBROUTINE SETS

The main function of subroutine SETS is to interrogate the data inputted by subroutine INBS and compute various sets of integers which will enable the computer to avoid redundant and trivial computation. To save computer storage, code words are created that compact the desired integer arrays into a single integer code word. Triangular arrays are stored as one-dimensional arrays in the memory of the computer. The following variables, defined

in table 1, are either first introduced or used extensively in subroutine SETS. The programmer is referred to the comment cards inserted therein and the following for detailed definitions.

- SG code word used to define the body labels of all gyrostats; i.e., all bodies that have one or more imbedded symmetric wheels.
- SI (KN) one dimensional array of code words used to define the body labels of all bodies on the topological path extending from hinge point K-1 outward to the center of mass of body N, where

$$KN = KTO(NBOD, K-1, N)$$

$$K = 1, 2, \dots, NBOD$$

$$N \ge K$$

The utility function KT0 is used to store the triangular array of code words in a one-dimensional array.

- SK (K-1) code word used to define the body labels of those bodies contained in the nest of bodies K-1; K = 1, 2, ..., NBOD. Due to the setup of labeled common block /INTGZ/, SK(0) is stored in the location SKDUM.
- SL code word used to define the body labels of all point masses.
- SQF (K) lowest magnitude free coordinate vector label at hinge point K-1; K = 1, 2, ..., NBOD+1, where

$$K = NBOD+1$$
 implies the inertial origin

and

$$SQF(K) = 0$$
 if $PCON(K) = 3$

SQL (K) – lowest magnitude locked coordinate vector label at hinge point K-1;
 K = 1, 2, ..., NBOD+1, where

$$K = NBOD+1$$
 implies the inertial origin

and

$$SOL(K) = 0$$
 if $PCON(K) = 0$

SR – code word used to define the body labels of all rigid and flexible bodies.

DATA INPUT, SUBROUTINE INOPT

Subroutine INOPT is the second input subroutine called by the MAIN program. The input cards to be read by it follow immediately after those read by subroutine INBS in the data deck.

The program N-BOD2 has been coded to accept a description of the basic simulation model by subroutine INBS. Amplifications or modifications to the model or to the equations of motion that describe it are defined by subroutine INOPT.

In many problems of practical interest, the user will not have to exercise any of the available options. In such cases all parameters required for computation, which could have been user defined, are set by default to the values that, in the author's opinion, are most commonly desired. If no options are to be used, INOPT will read only one data card.

INOPT is programmed to recognize different code words that are used to define which of the available options is to be used. The code words are punched on what will be referred to as "option cards." All option cards are read at program point 12 in INOPT by the statement

12 READ 100, ICD1, ICD2, ICD3, I, NSET, (S1 (J), J=1, 10)
100 FORMAT (3A4, I3, 11I5)

Columns 1 through 12 of each option card contain the code word. Table 6 contains a listing of all code words, the columns in which the alphanumeric characters must be punched, and a brief description of the function of the option.

Upon recognition of a code word, the program branches to the appropriate point in the program where all required computational and additional READ data operations are carried out. Upon completion, the program branches back to program point 12 to read the next option card. The cycling back to program point 12 continues until an END OPTIONS option card is recognized. The END OPTIONS card is the last card to be read by INOPT.

If a code word is not recognized, the flag FG3 will be set .FALSE., an error message will be printed, and return to the MAIN program will be immediately made.

The following subsections define in detail the various option codes recognized by INOPT and their purpose.

*** Terminate Option Input ***

1. No Option Required

If no options are required for the simulation model, the code word NO OPTIONS must be punched on the data card immediately following the data cards read by subroutine INBS. In this case, all modifiable parameters are set by default. The NO OPTIONS card would, in this case, be the only card read by INOPT.

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Table 6
Option Codes Recognized by INOPT and Function

GODDARD SPACE FLIGHT CENTER FORTRAN CODING RECORD

GPAM		PUNCHING	GRAPHIC		PAGE	OF	
CRAMMER.	DATE	INSTRU . ION'	PUNCH		CARD E	ECTRO NUMBER	
TATEMENT S	FORTRAN STATE	EMENT				IDENTIFICAT	
3 4 3 6 7 8 9	1	60 12 43 44 45 41	47 48 49 50 51 52 53 54 35 54	27 28 39 60 61 62 63 64 6	5 64 67 44 49 20 71 72	73, 74, 75, 74, 77, 71	
PTION CODE	PUNCTION OF OPTION	+++++	 		++++++		
O DETIONS	WO OPTION CARDS TO BE RE	An	 	 	╿	+++++	
ND OPTIONS	END OF OPTION CARDS				1111111		
IMERTIAL	USE INERTIAL COORDINATES	500 00	PUTATION		1111111		
BODY	USE BODY I COORDINATES F				1111111	+++++	
ASETX	MODIFY ARRAY SPI	7 77 77	77777		1111111	111111	
ASETIXC	MODIFY ARRAY SIX		1111111111		1111111		
ASETCEN	MODIFY ARRAY SCH		 	111111111	1111111		
ASETCOR	MODIFY ARRAY SCR						
EULERANG	MODIFY ARRAY SEU				1111111		
SMALLANG	MODIFY ARRAY SMAL						
VILABOD	MODIFY ARRAY SWO						
FREE	MODIFY ARRAY SER						
LOCK	MODIFY ARRAY SAK						
MOMANGLE	MODIFY ARRAY SAA						
CFORCE	MODIFY ARRAY SFK						
VARWHEEL	MODIFY ARRAY SAY						
COLX	MODIFY ARRAY SXT						
CAGE	SOME DEGREES OF FREEDOM	CAGED					
FLEXIBLE	SOME BODIES ARE TO BE FL						
MODE CUP	SOME VIBRATION MODES CRO	SS-COUP	LED				
4 5 6 7 8 9 10 11 12 12 14 16 (-1(12/00)	15 16 17 18 19 20 21 22 21 24 25 24 27 26 27 38 39 30 31 32 33 34 35 34 37 31 31	N 11 22 23 44 23 44	4 4 4 8 3 3 5 5 5 5 5	SANGGONE	H D H H M T M	A DEDIDEDADE	

2. End Options

If the user is to make use of one or more options, the last card of the cards to be read by INOPT must have the code word END OPTIONS punched on it. If it does not, an input error will result and the program will terminate with an appropriate error message.

*** Optimize Computation Efficiency ***

In order to optimize computation speed, all unnecessary, trivial, and redundant computation must be avoided. By an interrogation of the input data, numerous sets of integers can be defined that can be used to carry out the above task. It is not possible for the computer to pick out "almost trivial" computations; this the engineer must do. By use of particular option cards, he can literally insert engineering judgment into N-BOD2.

In practical application, the author has found that usually there are not enough "almost trivial" terms that can be justifiably deleted to make a significant impact on computation speed. Consequently, while the options are available for the user, the author has rarely made practical use of most of them.

3. Choice of Frame of Computation

The equations of motion, as derived, are in a vector-dyadic form and are valid for all frames of reference. The user may choose the frame of computation to be either the inertially fixed-reference frame or the body 1 fixed-reference frame. All vectors and tensors required for computation are stored in memory in computing frame coordinates. The user should define the frame of computation to be the reference frame in which he wishes to output most of the computed system state variable vectors.

The logic variable INERF is used to define which frame of computation is to be used for internal computation.

INERF = .TRUE. if the frame of computation is to be the inertially fixed-reference frame. Recognition of the code word INERTIAL on an option card will set INERF equal to .TRUE.

INERF = .FALSE. if the frame of computation is to be the body.1 fixed-reference frame. Recognition of the code word BODY 1 on an option card will set INERF equal to .FALSE.

Default INERF = .FALSE.

Body 1 will be the frame of computation unless otherwise directed.

4. Truncate Computation of Pseudo-inertia Tensors

The vector-dyadic form of the simulation model's equations of motion is given in Reference 1 by equation 88 and in Reference 2 by equation 111. The coefficient matrix on the left-hand side of the equation contains numerous inertia and pseudo-inertia tensors that are

defined by equations 63 through 70 of Reference 1. If the simulation model has both large and small bodies, some of the small bodies may contribute a nearly trivial amount to the pseudo-inertia tensors associated with the nests that contain both the large and the small bodies.

To compute the inertia and pseudo-inertia tensors defined by equations 63 through 70 of Reference 1, the integer code words SPI(I), I = 0, 1, ..., NBOD-1, are used in subroutine XDY.

SPI(I) – code word. Used to define the set of bodies contained in the nest I that contribute significantly in the computation of the inertia and pseudo-inertia tensors associated with the nest I; I = 0, 1, ..., NBOD-1.

Upon recognition of the code word ASETX, INOPT makes use of the data in columns 13 through 70 of the option card to redefine the code word SPI(I). The following definitions apply for this option:

I = nest number

NSET = number of body labels to be defined to be in the set defined by SPI(I)

(SI(J), J = 1, NSET) = the body labels defined to be in the set defined by SPI(I).

The code word SPI(I) is created by the operation

Default
$$SPI(I) = SK(I); I = 0, 1, ..., NBOD-1$$

Unless otherwise directed, all bodies contained in the nest I are assumed to contribute significantly to the inertia and pseudo-inertia tensors associated with the nest I.

5. Truncate Computation of Inertia Cross-Coupling Torques

In Reference 1, the inertia cross-coupling torque acting on the nest I can be found from equations 79 and 80. In Reference 2, it can be found in equation 92. It is given in the notation of these references as

$$\sum_{\lambda \in \mathbb{S}_{\mathbf{I}}} \left[\mathring{\Phi}_{\lambda} \cdot \overrightarrow{\omega}_{\lambda} + \overrightarrow{\omega}_{\lambda} \times \left(\Phi_{\lambda} \cdot \overrightarrow{\omega}_{\lambda} + \overrightarrow{\Delta L}_{\lambda, \lambda} \right) \right]$$

where the summation extends over all bodies contained in the nest I. In subroutine ETA, the integer code words SIX(I), I = 0, 1, ..., NBOD-1, are used to define which bodies contribute significantly to the above summation.

SIX(I) - code word. Used to define the set of bodies contained in the nest I that contribute significantly to the computation of the inertia cross-coupling torque acting on the nest I; I = 0, 1, ..., NBOD-1.

Upon recognition of the code word ASETIXC, INOPT makes use of the data in columns 13 through 70 of the option card to redefine the code word SIX(I). The following definitions apply for this option:

I = nest number

NSET = number of body labels to be defined to be in the set defined by SIX(I).

(SI(J), J = 1, NSET) =the body labels defined to be in the set defined by SIX(I).

The code word SIX(I) is created by the operation

<u>Default</u> Unless otherwise directed, all rigid and flexible bodies contained in the nest I are assumed to contribute significantly to the inertia cross-coupling torque acting on the nest I.

NOTE: Point masses have zero contribution and hence their body labels are not contained in any of the sets defined by the code words SIX(I); I = 0, 1, ..., NBOD-1.

6. Truncate Computation of Centripetal and some of the Coriolis Cross-Coupling Torques

In Reference 1, the centripetal and Coriolis cross-coupling forces and torques appearing on the right-hand side of equation 88 are defined by equations 75 through 78. In Reference 2, the analogous terms are found in equations 100, 107, and 108.

In the notation of Reference 2, the gyroscopic torque associated with these effects acting on the nest I is given by

$$\sum_{\lambda \in S_{I}} \vec{\gamma}_{I,\lambda} \times \vec{C}_{\lambda} \qquad ; I = 0, 1, ..., NBOD-1$$

where

$$\vec{C}_{\lambda} = m_{\lambda} \left[\sum_{i \in S_{0,\lambda-1}} \left(\vec{\omega}_{J(i)} \times \left(\vec{\omega}_{J(i)} \times \vec{\beta}_{i} \right) + 2 \vec{\omega}_{J(i)} \times \vec{\beta}_{i} \right) \right]$$

$$+ \vec{\omega}_{\lambda} \times \left(\vec{\omega}_{\lambda} \times \vec{\alpha}_{\lambda} \right) + 2 \vec{\omega}_{\lambda} \times \overset{\circ}{\vec{\alpha}_{\lambda}} \right)$$

and the summation extends over all bodies contained in the nest I.

In subroutine ETA, the integer code words SCN(I) and SCR(I), I = 0, 1, ..., NBOD-1, are used to define which bodies contribute significantly to the above summation.

- SCN(I) code word. Used to define the set of bodies contained in the nest I which contribute significantly to the computation of the centripetal and Coriolis cross-coupling torques acting in the nest I; I = 0, 1, ..., NBOD-1.
- SCR(I) code word. Used to define the set of point masses contained in the nest I for which their Coriolis acceleration effects contribute significantly to the computation of the centripetal and Coriolis cross-coupling torques acting on the nest I; I = 0, 1, ..., NBOD-1.

Upon recognition of the code words ASETCEN or ASETCOR, INOPT makes use of the data in columns 13 through 70 of the option card to redefine the code words SCN(I) or SCR(I) respectively. The following definitions apply for these options:

I = nest number

NSET = number of body labels to be defined by SCN(I) or SCR(I), respectively.

(S1 (J), J = 1, NSET) = the body labels defined to be in the set defined by SCN(I) or SCR(I), respectively.

The code word SCN(I) is created by the data on the ASETCEN option card by the operation CALL COMPAC (S1, NSET, SCN(I)).

The code word SCR(I) is created by the data on the ASETCOR option card by the operation CALL COMPAC (S1, NSET, SCR(I)).

Unless otherwise directed, all bodies contained in the nest I are assumed to contribute to the centripetal and Coriolis cross-coupling torques acting on the nest I; I = 0, $1, \ldots, NBOD-1$.

NOTE: The elements of sets defined by the code words SCR(I), I = 0, 1, ..., NBOD-1, are only pointmass body labels.

7. Choice of Kinematic Techniques

The user has the choice of which type of kinematic formulation should be used to define the transformation matrices. In the first version of N-BOD2, direction cosine techniques were used exclusively. In an attempt to improve computation speed, it was noted that the integration of the equations of motion yielded Euler angles directly. These could be used to directly obtain the required transformation matrices and eliminate the need for setting up and integrating six direction cosine equations per transformation matrix. It was further reasoned that time-consuming trigometric operations could also be dropped if it was known that the Euler angles would be small angles. Practical application has shown that the computational operations required to go from Euler angles or small Euler angles to the transformation matrices takes about the same amount of computer time as the operations required to set up and integrate the direction cosine equations.

These three approaches are available for the user in N-BOD2. The author personally uses direction cosine techniques for most simulation work; however, if it is critical that the transformation matrices maintain orthonormality to a high degree of accuracy, Euler angle techniques are preferable. There is no significant computational speed advantage associated with any of the techniques. The Euler angle and small angle approach requires that the body fixed free vectors, about which the Euler angles are measured, be aligned with the coordinate axes of their respective body fixed-reference frames; a restriction not imposed in the direction cosine approach.

In subroutine DCT, the direction cosine equations are set up and in subroutine TRAN, transformation matrices are computed. The code words SD, SEU, and SMAL are used in these subroutines to define the particular kinematic approach that is to be used.

- SD = code word. Used to define all contiguous pairs of bodies (JCON(1), I) for which direction cosine techniques are used to compute transformation matrices.
- SMAL = code word. Used to define all contiguous pairs of bodies (JCON(I), I) for which small angle techniques are used to compute transformation matrices.
- SEU = code word. Used to define all contiguous pairs of bodies (JCON(1), 1) for which Euler angle techniques are used to compute transformation matrices.

Upon recognition of the code word EULERANG, the data in columns 13 through 70 are used to create the code word SEU by the operation

CALL COMPAC (S1, NSET, SEU).

Upon recognition of the code word SMALLANG, the data in columns 13 through 70 are used to create the code word SMAL by the operation

CALL COMPAC (S1, NSET, SMAL).

NOTE: Redundancy is not permitted. Pairs of bodies defined by the user to be in either of the sets defined by SEU or SMAL will be subtracted from the set defined by SD In columns 13 through 17 of the option cards,

I = unused

NSET = the number of pairs of bodies for which the special kinematic techniques are to be used.

(S1 (J), J = 1, NSET) = the labels defining the pairs. The Jth pair is defined as body JCON(SI(J)) and body SI(J).

<u>Default</u> Unless otherwise directed, all contiguous pairs of rigid or flexible bodies are contained in the set defined by SD. Both SEU and SMAL are empty sets unless otherwise directed.

8. Suppress Selected Coordinate Transformations

All nontrivial body fixed vectors and tensors are transformed to computing frame coordinates four times per integration step. Under certain conditions, this can be a wasteful operation. If it can be determined that the components of all body fixed vectors and tensors of certain bodies are essentially time invariant in computing frame coordinates, it makes no sense to retransform them at every integration step.

The avoidance of these redundant transformations is controlled by the code word SVD in VDIV and TRANVD.

SVD - code word. Used to define the set of all bodies for which body-fixed vectors and tensors are time varying in the frame of computation.

Upon recognition of the code word VTINBOD, the data in columns 13 through 70 are used to create the code word SVD by the operation

CALL COMPAC (S1, NSET, SVD).

In columns 13 through 70 of the option card,

I = unused

NSET = the number of bodies for which body-fixed vectors and tensors are time varying in the frame of computation.

(S1 (J), J = 1, NSET) = the body labels defined to be in the set defined by SVD.

<u>Default</u> Unless otherwise defined, all body labels are contained in the set SVD. If the computing frame is the body 1 fixed-coordinate frame, body label 1 is automatically subtracted from SVD.

NOTE: Body labels associated with point masses are included in SVD since their nominal center-of-mass positions are given in their respective body-fixed coordinate system.

9. Suppress Recomputation of Elements of Coefficient Matrix of Inertia Tensors

In References 1 and 2, the matrix X is a symmetric (NB1) × (NB1) matrix of inertia and pseudo-inertia tensors, the elements of which are given by equations 63 through 70 in Reference 1. Under certain conditions, one or more of the columns (down to the diagonal) of this matrix will have nonzero entries that are nearly constant in time. Unless otherwise directed, the program recomputes these terms four times per integration step. The avoidance of these redundant computations in subroutine XDY is controlled by the code word SXT.

SXT — code word. Used to define the columns of the matrix X of psuedo-inertia tensors that have time-varying elements. X is symmetric and columns referred to extend down only to the diagonal element. Column NB1 always is taken as having time-varying elements. The elements of column K, K = 2, ..., NBOD, give the inertia contributions of the nest K-1 to the system's equations of motion.

Upon recognition of the code word COLX, the data in columns 13 through 70 are used to create the code word SXT by the operation

CALL COMPAC (S1, NSET, SXT).

In columns 13 through 70 of the option card

I = unused

NSET = the number of columns to have time-varying elements (not including column NB1, NB1 = NBOD + 1).

(S1 (J), J = 1, NSET) = the column numbers of the columns of X that will have timevarying elements.

Default Unless otherwise defined, all body labels are contained in the set SXT. This implies that all nonzero elements of **X** will be assumed to be time varying.

10. Suppress Computation of Relative Displacements

A redundancy exists in the computation of kinematics. All transformation matrices may be computed by a solution of direction cosine equations. Relative displacement angles, which provide basically the same information, are found by an integration of Euler rate equations. If direction cosine methods are used, it usually is not necessary to compute all relative displacement angles since their only use is for a description of torques acting between bodies that are a function of relative displacement angle (springs) and for output display. Accordingly, the user may selectively supress their computation.

The avoidance of the computation of relative displacement angles is controlled by the integer array SFR in subroutines SETUP and ANGLE.

NFRC – total number of free coordinate vectors about or along which relative displacement is to be computed.

SFR (I) - the labels associated with the free coordinate vectors about or along which relative displacement is to be computed. I = 1, 2, ..., NFRC

Upon recognition of the code word FREE, the data in columns 13 through 70 are used to define the elements of the set SFR. In columns 13 through 70 of the option card,

I = unused

NSET = the number of free coordinate labels to be defined on this card for inclusion is the set SFR.

(S1 (J), J = 1, NSET) = the free coordinate labels to be defined to be in the set SFR.

The input data format statement allows a maximum of 10 free coordinate vector labels to be defined per option card. Several option cards with the code word FREE may be used if required.

<u>Default</u> Unless otherwise defined, all relative displacement rate equations will be set up and integrated.

NOTE: INOPT is programmed to prohibit the user from supressing the computation of angles required for use in conjunction with either the Euler angle or the small angle option. It also prohibits the suppression of the computation of the coordinates that define body 1 translational displacement or point mass displacement.

11. Suppress Computation of Symmetric Wheel Angular Position

In spacecraft application, the integration of the symmetric wheel rate equation to ascertain the angular position of a mark on a symmetric wheel is usually a time-consuming and wasteful practice since its rates are usually high relative to the spacecraft frequencies of interest. At times, however, it may be important to know the wheel's angular position.

The determination as to which wheel rate equation should be integrated is controlled in sub-routine SETUP by the integer array SMA.

NMOA – total number of symmetric wheel rate equations to be integrated.

SMA (1) - the labels of the symmetric wheels for which wheel angular position is to be computed. I = 1, 2, ..., NMOA

Default Unless otherwise directed, none of the wheel rate equations will be integrated.

Upon recognition of the code word MOMANGLE, the data in columns 13 through 70 are used to define the elements of the set SMA. In columns 13 through 70 of the option card,

I = unused

NSET = the number of symmetric wheel labels to be defined on this card for inclusion in the set SMA.

(S1 (J), J = 1, NSET) = the symmetric wheel labels to be defined to be in the set

The input data format statement allows a maximum of 10 wheel labels to be defined per option card. Several option cards with the code word MOMANGLE may be used if desired.

12. Computation of Forces and Torques of Constraint

The code words CFORCE and LOCK are recognized and may be used to redefine the elements in the integer array SFK and SLK, respectively. These arrays were to be used to define which forces and torques of constraint should be computed. This option has not been coded and is not available for users of N-BOD2.

Default

NCTC = 0

NFKC = 0

SFK = 0

SLK = 0

*** Expand Modeling Capability ***

13. Specification of Constant Speed Wheels

Wheels that are controlled to spin at a constant speed should be modeled as constant speed wheels. Computationally, this reduces the order of the equations of motion of the system and eliminates the need for defining a control system that will maintain constant wheel rate.

The code word SMV is used in subroutines QFDOT and SETUP to define which wheels are to be treated as variable speed wheels.

SMV - code word. Used to define which of the symmetric wheels are to be treated as variable speed wheels; all others are treated as constant speed wheels.

NMV - total number of variable speed wheels.

Upon recognition of the code word VARWHEEL, the data in columns 13 through 70 are used to create the code word SMV by the operation

CALL COMPAC (S1, NSET, SMV).

In columns 13 through 70 of the option card,

I = unused

NSET = number of wheels to be defined as variable speed wheels.

(S1 (J), J = 1, NSET) =the labels of the variable speed wheels.

Only one VARWHEEL option card is permitted.

<u>Default</u> Unless otherwise directed, all symmetric wheels are assumed to be variable speed wheels.

14. Caging and Uncaging of Degrees of Freedom

In order to simulate the deployment of spacecraft appendages, it is desirable to have the capability to increase the number of allowable degrees of freedom during a simulation run. A "caged degree of freedom" is a degree of freedom that is not allowed for a predefined time. The uncaging of degrees of freedom at predefinable times allows the user to simulate deployment transients.

The following definitions are used:

SCG - total number of caged degrees of freedom at time zero.

SC (I) - labels of the free coordinate vectors about or along which relative motion will be constrained for a predefined time. I = 1, 2, ..., SCG

TUG (I) - time at which motion about or along free coordinate vector SC(I) will be allowed (uncaged). I = 1, 2, ..., SCG

NOTE: All uncaging takes place with zero initial relative rate. The coding to account for the impulse effect that is associated with uncaging with an initial relative rate has not been included in N-BOD2.

Upon recognition of the code word CAGE, the procedure for inputting the data required to use this option is started. In columns 13 through 70 of the option card,

I = unused

NSET = SCG, the total number of degrees of freedom caged at time zero.

(S1(J), J = 1, NBOD) = unused.

Their labels and times for uncaging are then read according to the following:

After these data cards are read, a check is made to make sure that the initial rates associated with the caged degrees of freedom are zero. If not, they are reset to zero.

<u>Default</u> Unless otherwise directed, all degrees of freedom are assumed uncaged at time zero.

15. Flexible Body Option

The user is encouraged to first refer to the section entitled "Flexible versus Rigid Body Modeling" in Reference 2 before making use of the flexible body option. Contained therein are equations that provide a guide for estimating the required number of vibration modes and a discussion of the assumptions implicit in the formulation of the coupled flexible body equations of motion.

N-BOD2 accepts only resultant mode dependent parameters. Their description is based upon the assumption that a finite element model of the flexible body can be defined.*

The following definitions are taken directly from Reference 2 and are used to define the required resultant mode dependent parameters.

 $m_{i,\lambda}$ = mass of element i of body λ

 $^{o}\Phi_{i,i,\lambda}$ = inertia tensor of element i of body λ about its own center of mass in the undeformed state of body λ

 $\vec{or}_{i,\lambda}$ = position vector from hinge point λ -1 to the undeformed center-of-mass position of the element i of body λ

 $^{\circ}$ $\vec{\alpha}_{\lambda}$ = position vector from hinge point λ-1 to the undeformed center-of-mass position of body λ

 $\vec{\nabla}_{n,i,\lambda}^{T}$ = nth normal mode displacement vector for the element i of body λ

 $\vec{\varphi}_{n+\lambda}^{R}$ = nth normal mode rotation vector for the element i of body λ

 m_{λ} = total mass of body λ

 $\delta_{m,n}$ = Kronecker delta function

 $N_{t,\lambda}$ = total number of elements i used in the finite element model of body λ

^{*}The user is also referred to Appendix B in which a NASTRAN DMAP program and a preprocessor program are listed. The output of these two programs define the resultant mode dependent parameter required.

The normalization condition imposed upon the modes is

$$\sum_{\mathbf{i} \in \lambda} \left[m_{\mathbf{i},\lambda} \overrightarrow{\varphi}_{\mathbf{m},\mathbf{i},\lambda}^{\mathsf{T}} \cdot \overrightarrow{\varphi}_{\mathbf{n},\mathbf{i},\lambda}^{\mathsf{T}} + \overrightarrow{\varphi}_{\mathbf{m},\mathbf{i},\lambda}^{\mathsf{R}} \cdot \left({}^{\circ} \Phi_{\mathbf{i},\mathbf{i},\lambda} \cdot \overrightarrow{\varphi}_{\mathbf{n},\mathbf{i},\lambda}^{\mathsf{R}} \right) \right] = m_{\lambda} \delta_{\mathbf{m},\mathbf{n}}$$

where

$$\lim_{N_{i,\lambda}\to\infty} \sum_{i\in\lambda} \overrightarrow{\varphi}_{m,i,\lambda}^{R} \cdot \left({}^{\circ}\Phi_{i,i,\lambda} \cdot \overrightarrow{\varphi}_{n,i,\lambda}^{R} \right) = 0$$

The resultant mode dependent parameters required as input data to N-BOD2 are given by equations 48, 50, 51, 54, 55, 67, 70, and 72 in Reference 2. They are

$$\vec{A}_{n,\lambda} = \frac{1}{m_{\lambda}} \sum_{i \in \lambda} m_{i,\lambda} \vec{\varphi}_{n,i,\lambda}^T$$

$$\mathbf{D}_{\mathbf{n},\lambda} = \sum_{i \in \lambda} \mathbf{m}_{i,\lambda} \left[\left(\stackrel{\circ}{\mathbf{r}}_{i,\lambda} - \stackrel{\circ}{\mathbf{\alpha}}_{\lambda} \right) \cdot \stackrel{\rightarrow}{\varphi}_{\mathbf{n},i,\lambda}^{\mathsf{T}} \mathbf{1} - \left(\stackrel{\circ}{\mathbf{r}}_{i,\lambda} - \stackrel{\circ}{\mathbf{\alpha}}_{\lambda} \right) \stackrel{\rightarrow}{\varphi}_{\mathbf{n},i,\lambda}^{\mathsf{T}} \right]$$

$$\overrightarrow{B}_{n,\lambda} = \frac{1}{m_{\lambda}} \sum_{i \in \lambda} m_{i,\lambda} \circ \overrightarrow{r}_{i,\lambda} \times \overrightarrow{\varphi}_{n,i,\lambda}^{T}$$

$$\vec{C}_{n,\lambda} = \sum_{i \in \lambda} \circ \Phi_{i,i,\lambda} \cdot \vec{\varphi}_{n,i,\lambda}^{R}$$

$$\mathbf{J}_{\mathbf{n},\lambda} = \sum_{i \in \lambda} \overrightarrow{\varphi}_{\mathbf{n},i,\lambda}^{\mathbf{R}} \times {}^{\diamond} \Phi_{i,i,\lambda}$$

$$\mathbf{F}_{\mathbf{m},\mathbf{n},\lambda} = \sum_{i \in \lambda} \mathbf{m}_{i,\lambda} \left[\overrightarrow{\varphi}_{\mathbf{m},i,\lambda}^{\mathsf{T}} \cdot \overrightarrow{\varphi}_{\mathbf{n},i,\lambda}^{\mathsf{T}} \mathbf{1} - \overrightarrow{\varphi}_{\mathbf{m},i,\lambda}^{\mathsf{T}} \overrightarrow{\varphi}_{\mathbf{n},i,\lambda}^{\mathsf{T}} \right]$$

$$\vec{K}_{m,n,\lambda} = \sum_{i \in \lambda} \left\{ m_{i,\lambda} \vec{\varphi}_{m,i,\lambda}^{T} \times \vec{\varphi}_{n,i,\lambda}^{T} + \frac{1}{2} \left({}^{\circ}\Phi_{i,i,\lambda} \cdot \vec{\varphi}_{m,i,\lambda}^{R} \right) \times \vec{\varphi}_{n,i,\lambda}^{R} \right\}$$

If mode shapes are obtained by a continuum analysis, the rotational inertia effects of the infinitesimal elements about their respective centers of mass is negligible; hence

and

$$\lim_{N_{i,\lambda} \to \infty} \left[\sum_{i \in \lambda} m_{i,\lambda} \vec{\varphi}_{m,i,\lambda}^{\mathsf{T}} \cdot \vec{\varphi}_{n,i,\lambda}^{\mathsf{T}} - m_{\lambda} \delta_{m,n} \right] = 0$$

The other mode-dependent parameters that are used or computed are:

 ω_n - natural frequency of mode n of body λ (rad/...)

 ζ_n - damping ratio for mode n of body λ

 $a_{n,\lambda}(t)$ - generalized displacement coordinate for mode n of body λ

 $\dot{a}_{n,\lambda}(t)$ - generalized displacement coordinate rate for mode n of body λ

The position vector from the undeformed to the deformed center-of-mass position of the element i of body λ is

$$\vec{\epsilon}_{i,\lambda} = \sum_{n,\lambda} a_{n,\lambda}(t) \vec{\varphi}_{n,i,\lambda}^{T}$$

where the summation is overall modes defined for body λ .

The following parameters are defined in subroutine INOPT and used within the various subroutines to compute the effects of body flexibility:

NFLXB - total number of flexible bodies

SFXM (I) – total number of flexible body modes to be used to describe the flexible body characteristics of body I (zero if body I is a rigid body or a point mass); I = 1, 2, ..., NBOD.

SFLX – code word used to define the body labels of those bodies that are to be treated as flexible bodies.

NMODS - total number of flexible body modes used for entire simulation model.

Upon recognition of the code word FLEXIBLE, the procedure for inputting uncoupled modal data starts. In columns 13 through 70 of the option card,

I = unused

NSET = total number of bodies to be defined to be flexible.

(S1 (I), I = 1, NBOD) = the number of flexible body modes to be used to describe the flexible body characteristics of body I; I = 1, 2, ..., NBOD. (Zero if body I is a rigid body or point mass).

The parameters NFLXB, SFXM, SFLX, and NMODS are computed by an internal process that makes use of the above data provided on the option card.

To conserve computer storage and increase computation speed, all mode-dependent parameters are sequentially numbered from 1 to NMODS by an internally defined algorithm that makes use of the SFXM integer array. All parameters associated with mode M of body K are given the integer label MN which is computed by the algorithm

$$MN = M + \sum_{i=1}^{K-1} SFXM(i)$$

where

$$K = 2, 3, ..., NBOD$$

and

$$M = 1.2....SFXM(K)$$

MN will be referred to as the "mode number."

All uncoupled mode-dependent data required by N-BOD2 are read immediately after recognition of the code word FLEXIBLE on an option card. For mode M of flexible body K, the following data must be defined. Its mode number MN is defined as

$$MN = M + \sum_{i=1}^{K-1} SFXM(i)$$

and recall that

NFER = total number of free coordinate vectors.

Then

FLOM (MN) = $\omega_{M,K}$ the modal natural frequency (rad/...)

ZETA (MN) = $\zeta_{M,K}$ the modal damping ratio

```
= a_{M,K} (t) generalized displacement coordinate (initial value to be
THA (NFER + MN)
                          inputted)
THAD (NFER + MN) = \hat{a}_{M,K} (t) the generalized displacement coordinate rate (initial value
                          to be inputted)
                       = components of the resultant mode-dependent vector \vec{A}_{MK} relative
FLA (I, MN)
                          to the body K fixed reference frame.
                       = components of the resultant mode-dependent vector \vec{B}_{M,K} relative
FLB (I, MN)
                          to the body K fixed reference frame.
FLC (I, MN)
                       = components of the resultant mode-dependent vector \overrightarrow{C}_{M,K} relative
                          to the body K fixed reference frame.
                       = components of the resultant mode-dependent dyad D<sub>M,K</sub> relative
[FLD(I, J, MN)]
                          to the body K fixed reference frame.
                       = components of the resultant mode-dependent dyad J_{M,K} relative
[FLJ (I, J, MN)]
                          to the body K fixed reference frame.
```

The data required to describe the uncoupled modal data for each flexible body are read according to the following sequence of read statements.

```
********* KEAD STATEMENTS FOR OPTION *FLEXIBLE* IN INDEX GOUGGEORGES
    INITIALIZE MODE LAHELS
DO 1 K=1.NHOD
    IFISEXMIKI.ED.O) GO TO I HODY & IS NOT A PLEXIBLE HODY
    IF(K.NF.N) ERROR. CAROS OUT OF SEQUENCE. PRINT MESSAGE MALT
      N = BODY LAKEL FOR WHICH FLEXIBLE HODY DATA TO FOLLOW APPLIES
    MESS = ALPHANIMERIC DESCRIPTION OF HODY N. PRINTED WITH DATA FCHO
RODREDGE OF THE TOTAL PARTY SEXMIK! SETS HE MODAL DATA FOR HODY & REGERESE
    DO 2 M =1.5FXM(K)
    MN = MN + 1
    READ 104. FLOM (MN) . 7ETA (MN)
    READ 104. THA (NEEH+MM) . THAD (NEEH+MN)
    RFAD 104. (FLA([.MN). 1=1.3)
    READ 104. (FLR(1.MN).1=1.3)
    KEAD 104. (FLC(1.MN). 1=1.3)
    2 CONTINUE
HORROGOROGO ALL UNCOUPLED MODAL DATA FOR RODY K HAS REEN READ HURBHURHE
0
   1 CONTINUE
```

```
C C FORMAT STATEMENTS
103 FORMAT (15.1844)
104 FORMAT (3015.5)
```

The input of the coupled modal data follows the option card 'MODE CUP.'

In the process of developing the equations that define centripital and Coriolis related loads associated with flexible bodies, certain mode-dependent, cross-coupling parameters are derived; namely $\mathbf{F}_{m,n,\lambda}$ and $\widetilde{\mathbf{K}}_{m,n,\lambda}$ (previously defined in this section). In many practical applications, most, if not all, of these terms are identically or nearly equal to zero. Computer time and storage can be conserved by developing a scheme which will only use nontrivial cross-coupling terms.

The following parameters are defined in subroutine INOPT and used in subroutine QFDOT to compute the modal cross-coupling effects.

SFCC = code word. Used to define the body labels of the flexible bodies that have flexible body modes that are cross coupled (significantly).

SCXC (MN) = code word. Used to define the modes M of body K which significantly cross couple in the generalized displacement coordinate equation for the mode having mode number MN

$$MN = N + \sum_{i=1}^{K-1} SFXM(i)$$

From equation 95 of Reference 2, the cross-coupling terms in the equation for the generalized displacement coordinate associated with mode n of body λ are

$$\vec{\omega}_{\lambda} \cdot \left[\sum_{m,\lambda} \mathbf{F}_{m,n,\lambda} \mathbf{a}_{m,\lambda}(t) \right] \cdot \vec{\omega}_{\lambda} - 2\vec{\omega}_{\lambda} \cdot \sum_{m,\lambda} \mathbf{i}_{m,\lambda}(t) \vec{K}_{m,n,\lambda}$$

More simply expressed, the SCXC array defines which modes m of body λ shall be used in evaluating the above summations.

In the input deck, the code word MODE CUP must follow FLEXIBLE. Upon recognition of the code word MODE CUP, the procedure for inputting coupled modal data starts. In columns 13 through 70 of the option card,

I = unused

NSET = unused

(S1 (I), I = 1, NBOD) = number of blocks of mode dependent cross coupling data to be read in for body I; a block of data consists of the three integers (M, N, K), the components of the tensor F_{M,N,K}, and the components of the vector K_{M,N,K}

The parameter SFCC is computed by an internal process which makes use of the above data provided on the option card.

To conserve computer storage and increase computational speed, all coupled mode-dependent data are sequentially numbered. Strict adherence to the following input logic is required.

```
\begin{split} &\mathsf{MN} = 0 \\ &\mathsf{KF} = 0 \\ &\mathsf{DO} \ 1 \ \mathsf{K} = 1, \mathsf{NBOD} \\ &\mathsf{DO} \ 1 \ \mathsf{K} = 1, \mathsf{NBOD} \\ &\mathsf{DO} \ 1 \ \mathsf{N} = 1, \mathsf{SFXM}(\mathsf{K}) \\ &\mathsf{MN} = \mathsf{MN} + 1 \\ &\mathsf{DO} \ 1 \ \mathsf{M} = 1, \mathsf{SFXM}(\mathsf{K}) \\ &\mathsf{IF} \ \left[ \mathbf{F}_{\mathsf{M},\mathsf{N},\mathsf{K}} \ \mathsf{INSIGNIFICANT} . \mathsf{AND} . \ \vec{\mathsf{K}}_{\mathsf{M},\mathsf{N},\mathsf{K}} \ \mathsf{INSIGNIFICANT} \right] \ \mathsf{GO} \ \mathsf{TO} \ 1 \\ &\mathsf{READ} \ \mathsf{M}, \mathsf{N}, \mathsf{K} \\ &\mathsf{KF} = \mathsf{KF} + 1 \\ &\mathsf{READ} \ \mathbf{F}_{\mathsf{M},\mathsf{N},\mathsf{K}} \ \mathsf{and} \ \vec{\mathsf{K}}_{\mathsf{M},\mathsf{N},\mathsf{K}} \\ &\mathsf{LOAD} \ \mathbf{F}_{\mathsf{M},\mathsf{N},\mathsf{K}} \ \mathsf{into} \ \mathsf{FCF} \ \mathsf{array}, \ \mathsf{starting} \ \mathsf{at} \ \mathsf{location} \ (1,1,\mathsf{KF}) \\ &\mathsf{LOAD} \ \vec{\mathsf{K}}_{\mathsf{M},\mathsf{N},\mathsf{K}} \ \mathsf{into} \ \mathsf{FCK} \ \mathsf{array}, \ \mathsf{starting} \ \mathsf{at} \ \mathsf{location} \ (1,\mathsf{KF}) \\ &\mathsf{ADD} \ \mathsf{integer} \ \mathsf{M} \ \mathsf{to} \ \mathsf{code} \ \mathsf{word} \ \mathsf{SCXC}(\mathsf{MN}) \\ &\mathsf{1} \ \mathsf{CONTINUE} \end{split}
```

where

MN — mode number for mode N of body K
 KF — storage location integer designator for modal cross-coupling parameters
 [FCF(II,JJ,KF)] — components of the resultant coupled mode-dependent tensor

 F_{M,N,K} relative to the body K fixed reference frame (if M = N, significant terms usually exist)

 [FCK(II,KF)] — components of the resultant coupled mode dependent vector

 K_{M,N,K} relative to the body K fixed reference frame.

All coupled mode-dependent data required by N-BOD2 are read immediately after recognition of the code word MODE CUP on an option card. If flexible bodies are defined and the 'MODE CUP' option card and associated data are not in the option deck, all computation required to define modal cross-coupling effects is skipped.

The data required to describe the coupled modal data for each flexible body are read according to the following sequence of read statements:

```
READ STATEMENTS FOR OPTION 'MODE CUP' IN INOPT
C
     INITIALIZE COUPLED MODE LABELS
C
    KF = 0
C
              READ ALL NON-TRIVIAL COUPLED MODE PARAMETERS
C
    DO 1 K = 1, NBOD
C
             = NUMBER OF DATA BLOCKS FOR BODY K
C
    S1(K)
    SFXM(K) = NUMBER OF MODES USED FOR BODY K
    IF(SFXM(K).EQ.0) GO TO 1 (BODY K IS RIGID)
    IF(SI(K).NE.0.) GO TO 2
                             (SOME CROSS COUPLING FOR BODY K)
    GO TO 1
  2 DO 1 M = 1, S1(K)
    READ 105 MB, NB, KB
    KF = KF + 1
    READ 104, (FCF(II,JJ,KF),JJ = 1, 3),II = 1, 3)
    READ 104, (FCK(II, KF), II = 1, 3)
  1 CONTINUE
C
                       ALL COUPLED MODAL DATE IN
C
C
C
    FORMAT STATEMENTS
104 FORMAT (3E15.5)
105 FORMAT (315)
```

<u>Default</u> Unless otherwise directed, the simulation model will consist only of rigid bodies, point masses, and symmetric wheels. All parameters associated with flexible bodies will be set equal to zero.

PROGRAMMER'S GUIDE TO SUBROUTINE INOPT

The main function of subroutine INOPT is to accept the data that will define the parameters associated with the various computational options available to the user. It is structured to

grow. As new modeling requirements are defined and their associated equations developed, INOPT is the subroutine in which the basic data required to define the new option are to be entered. This is done by simply defining another code word that will be recognized along with the FORTRAN coding required to set up the basic data necessary to describe the new option.

Subroutine INOPT has the following structure:

- Define by default all parameters associated with available options.
- Read option card and compare option code with library of recognizable codes.
- Branch to appropriate program point, redefine option-related parameters, input any additional data required.
- Branch back to program point 12 to read another option card.
- Upon recognition of the 'END OPTIONS' code word, check all option data for basic incompatabilities.
- Perform any final setup work that must be done after all option data have been inputted.
- Print an echo of all option related data defined in INOPT.

The following variables, defined in table 1, are either first introduced or used extensively in subroutine INOPT. The programmer is referred to the comment cards inserted therein, and the following, for detailed definition.

CT1	_	counter. Zeroed before exit from INOPT
CT2	_	counter. Zeroed before exit from INOPT
CT3	_	counter. Zeroed before exit from INOPT
CT4	_	counter. Zeroed before exit from INOPT (See DYN)
CT5	_	counter. Zeroed before exit from INOPT
[FCF(I,J,K)]	_	See section "Data Input/INOPT," subsection 15
$\{FCK(I,K)\}$		See section "Data Input/INOPT," subsection 15
FG3	-	input error flag. If the code word on any option card is not recognized, it is set to .FALSE.
{FLA(I,MN)}	-	See section "Data Input/INOPT," subsection 15
$\{FLB(I,MN)\}$		See section "Data Input/INOPT," subsection 15
$\{FLC(I,MN)\}$		See section "Data Input/INOPT," subsection 15
[FLD(I,J,MN)]	_	See section "Data Input/INOPT," subsection 15

[FLJ(I,J,MN)]	_	See section "Data Input/INOPT," subsection 15
FLOM(MN)	_	See section "Data Input/INOPT," subsection 15
INERF		See section "Data Input/INOPT," subsection 3
NCTC	_	See section "Data Input/INOPT," subsection 12
NFKC	_	See section "Data Input/INOPT," subsection 12
NFLXB		See section "Data Input/INOPT," subsection 15
NFRC	_	See section "Data Input/INOPT," subsection 10
NMOA	_	See section "Data Input/INOPT," subsection 11
NMODS	_	See section "Data Input/INOPT," subsection 15
NMV	-	See section "Data Input/INOPT," subsection 13
SC(I)	_	See section "Data Input/INOPT," subsection 14
SCXC(K)	_	See section "Data Input/INOPT," subsection 15
SCG	_	See section "Data Input/INOPT," subsection 14
SCN(I)	_	See section "Data Input/INOPT," subsection 6
SCR(I)		See section "Data Input/INOPT," subsection 6
SD	_	See section "Data Input/INOPT," subsection 7
SEU	_	See section "Data Input/INOPT," subsection 7
SFCC		See section "Data Input/INOPT," subsection 15
SFK(I)	-	See section "Data Input/INOPT," subsection 12
SFLX	_	See section "Data Input/INOPT," subsection 15
SFR(I)	-	See section "Data Input/INOPT," subsection 10
SFXM(I)	-	See section "Data Input/INOPT," subsection 15
SIX(I)	_	See section "Data Input/INOPT," subsection 5
SLK(I)	-	See section "Data Input/INOPT," subsection 12
SMA(I)		See section "Data Input/INOPT," subsection 11
SMAL		See section "Data Input/INOPT," subsection 7
SMC(K)	-	code word. Used to define the symmetric wheel labels associated with all wheels contained in the nest K-1; $K = 1, 2,, NBOD$
SMV	-	See section "Data Input/INOPT," subsection 13

SPI(I) - See section "Data Input/INOPT," subsection 4

SVD - See section "Data Input/INOPT," subsection 8

SXM(I,K) - computed integer array. Used in subroutine TRAN if the trans-

formation matrices for body K are to be computed using Eulerangle techniques. SXM(I,K) defines the coordinate axis $(\pm 1, \pm 2, \pm 3)$ in body K along which the free coordinate vector M+(I-1), I = 1, ..., 3-PCON(K), is aligned in the zero state (sign implies direction). It is computed only if needed; otherwise it is set to

zero.

SXT - See section "Data Input/INOPT," subsection 9

TUG(I) See section "Data Input/INOPT," subsection 14

ZETA(MN) - See section "Data Input/INOPT," subsection 15

DATA INPUT, SUBROUTINE INTOR

The third and last input data subroutine to be entered is INTOR. Normally this routine contains no executable instruction. It is for the user. The user may insert any desired input statements and store the resultant data in common block /SATELL/. The data inputted here usually consist of all data needed to define the parameters in the user-defined description of the forces and torques acting on the simulation model.

There are no new variables introduced in this subroutine other than those that are user defined.

PROGRAMMER'S GUIDE TO SUBROUTINE TRNSIV

The primary purpose of the computation coded in subroutine TRNSIV is to compute initial values for all required transformation matrices. The user need never interface with this subroutine.

All required computation carried out in N-BOD2 is done relative to the frame of computation (see section "Data Input/INOPT," subsection 3). Consequently, transformation matrices which take vectors from body fixed coordinates to computing frame coordinates must be evaluated. TRNSIV computes the initial values of these matrices based upon the data inputted in subroutine INBS. Quarternion techniques are applied since gimbal axes need not be aligned with body fixed coordinate axes (see Reference 1, section "Initial Orientation of the N-Body System" and Appendix "Quarternion Techniques").

The following variables, defined in table 1, are first introduced in subroutine TRNSIV. All other variables used therein have been previously defined. The programmer is referred to the comment cards inserted in TRNSIV, and the following, for detailed definitions:

[XMC(I,J,K)]

for K = 0 - transformation matrix used to transform vectors from inertially fixed coordinates to the frame of computation.

for K = 1, 2, ..., NBOD - transformation matrix used to transform vectors from body K fixed coordinates to the frame of computation,

where

$$[XMC (1,J,K)] = \begin{bmatrix} XMC (1,1,K) & XMC (1,2,K) & XMC (1,3,K) \\ XMC (2,1,K) & XMC (2,2,K) & XMC (2,3,K) \\ XMC (3,1,K) & XMC (3,2,K) & XMC (3,3,K) \end{bmatrix}$$

For any particular problem, all computation carried out in TRNSIV can be outputted on the line printer by defining

on card 1 of the data deck. There is a one-for-one correspondence between the line printer output and the theoretical notation in Reference 1.

PROGRAMMER'S GUIDE TO SUBROUTINE VDIV

The initial values for all body fixed vectors and tensors, relative to the frame of computation, are computed in subroutine VDIV. The user need never interface with this subroutine.

All vector-tensor operations required to define the system equations of motion are carried out in computing frame coordinates. N-BOD2 attempts to avoid redundant and trivial computation by transforming all body fixed vectors and tensors, used more than once, into computing frame coordinates at time zero. Thereafter, integer sets, computed in VDIV, are used to transform, at every integration step, only those vectors and tensors that have non-trivial time-varying components relative to computing frame coordinates.

The following variables, defined in table 1, are first introduced in subroutine VDIV. All other variables used therein have been previously defined. The programmer is referred to the comment cards inserted in VDIV, and the following, for detailed definitions:

${CAC(1,K)}$ for $K = 1, 2,, NBOD$		components of the vector from hinge point K-1 to the deformed center-of-mass position of body K, relative to the frame of computation (see Reference 2, equation 47).
${CAO(1,K)}$ for K = 1, 2,, NBOD	-	components of the vector from hinge point K-1 to the undeformed center-of-mass position of body K, relative to body-K fixed coordinates.
${CBC(I,K)} $ for K = 0		unused. Reserved for the components of the vector from the inertial origin to the composite system center-of-mass, if needed.

for $K = 1, 2, \ldots, NBOD$	-	components of the vector from hinge point JCON(K)-1 to hinge point K-1, relative to the frame of computation (N-BOD2 assumes zero elastic deformation at hinge points).
{FLAC(I,MN)}	_	components of the mode-dependent vector defined by equation 48 of Reference 2 relative to the frame of computation. It is used in equation 47 to define the contribution of mode M deformation of body K to the vector which defines the deformed center-of-mass location of body K, where mode number MN is defined as
		$MN = M + \sum_{I=1}^{K-1} SFXM(I)$
		K = 2, 3,, NBOD M = 1, 2,, SFXM(K)
[FLE(I,J,MN)]	-	components of the mode-dependent tensor defined by equation 52 of Reference 2 relative to body K fixed coordinates. It is used in equation 49 to define the contribution of mode M deformation of body K to the deformed state inertia tensor of body K, where MN is the mode number defined as above.
[FLH(I,J,MN)]	-	components of the mode-dependent tensor defined by equation 68 of Reference 2 relative to body K fixed coordinates. It is used in equation 65 of Reference 2 to define a component of the generalized force acting on mode M of body K, where MN is the mode number defined as above.
{FLQ(I,MN)}	-	components of the mode-dependent vector defined by equation 56 of Reference 2 relative to the body K fixed reference. It is used in equation 53 of Reference 2 to compute the contribution of mode M deformation rate to the angular momentum of body K, where MN is the mode number as defined above.
{FLQC(I,MN)}	-	components of the mode-dependent vector defined by equation 56 of Reference 2 relative to the computing frame

frame.

{GAM(I,KL)}	_	unused in VDIV; however, all elements of the array
,		GAM are set equal to zero in VDIV.
${HMC(I,M)}$ for M = 1, 2,, MNO	-	components of the unit vector directed along the spin axis of symmetric wheel M relative to the frame of computation (N-BOD2 assumes zero elastic deformation at wheel attachment points).
NSVP	-	total number of locked coordinate vectors to be transformed to computing frame coordinates at every integration step.
NSVQ	-	total number of free coordinate vectors to be trans- formed to computing frame coordinates at every integration step.
${QFC(I,M)}$ for M = 1, 2,, NFER	-	components of free coordinate vector M relative to the frame of computation.
${QLC(I,L)} $ for L = 1, 2,, NLOR	-	components of locked coordinate vector L relative to the frame of computation.
SOK(K) for $K = 1, 2,, NBOD$	-	code word used to define the body labels of those bodies on the topological path from hinge point 0 to the center-of-mass of body K.
SOK(NBI) for NBI = NBOD+1	-	code word used to define the set of integers from 1 to NBOD+1 inclusive.
SSCN	-	code word used to define the union of all labels contained in the sets of integers defined by the code words $SCN(K)$; $K = 0, 1,, NBOD-1$.
SSIX	-	code word used to define the union of all labels contained in the sets of integers defined by the code words $SIX(K)$; $K = 0, 1,, NBOD-1$.
SVA	-	code word used to define the set of center-of-mass vectors that have nontrivial time-varying components in the frame of computation.
SVB		code word used to define the set of hinge-point vectors that have nontrivial time-varying components in the frame of computation.
SVI	***	code word used to define the set of inertia tensors that have nontrivial time-varying components in the frame of computation.

SVM	-	code word used to define the set of symmetric-wheel spin vectors that have nontrivial time-varying compo- nents in the frame of computation.
SVP(L) for L = 1, 2,, NSVP	-	the labels associated with the locked coordinate vectors that must be transformed at every integration step.
SVQ(M) for M = 1, 2,, NSVQ	-	the labels associated with the free coordinate vectors that must be transformed at every integration step.
[XDIC(I,J,IK)]	-	unused in VDIV; however, all elements of the array XDIC are set equal to zero in VDIV.
[XIC(1,J,K)] for $K = 1, 2,, NBOD$	-	components of the inertia tensor of body K about its center-of-mass in the deformed state relative to the frame of computation (see Reference 2, equation 49).
[XIO(I,J,K)] for $K = 1, 2,, NBOD$	-	components of the inertia tensor of body K about its undeformed center-of-mass position in the undeformed state relative to the body K fixed reference.

For any particular problem, all computation carried out in VDIV can be outputted on the line printer by defining

LVDIV = .TRUE.

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE EQIV

The complete description of the motion of the coupled-body system is defined by the simultaneous solution of a set of first-order, nonlinear, ordinary differential equations. Subroutine EQIV is used to compute the total number of first-order equations to be integrated (excluding those that are user defined) and to set up an array of initial conditions in a form compatible with the integration subroutine RUNGE. The user need never interface with this subroutine.

The following variables, defined in table 1, are first introduced in subroutine EQIV. All other variables used therein have been previously defined. The programmer is referred to the comment cards inserted in EQIV, and the following, for detailed definitions:

NEQ - total number of first-order differential equations that will be set up and numerically integrated via RUNGE (excluding those that are user defined in TORQUE).

In the coding of the equations of motion, the system state variables and their associated time derivatives are stored in various arrays which are given different symbolic names.

To effectively use the integration subroutine, these must all be reloaded into two onedimensional arrays so that the equations to be integrated take on the general form

$$\dot{\mathbf{y}}_{\mathbf{N}}(t) = f_{\mathbf{N}} \left[\dot{\mathbf{y}}_{1}(t), \dots, \dot{\mathbf{y}}_{\mathbf{NEQ}}(t), \mathbf{y}_{1}(t), \dots, \mathbf{y}_{\mathbf{NEO}}(t), t \right]$$

where

$$N = 1, 2, \dots, NEQ$$

Y(N)

 one dimensional array in which all state variables that are determined by integration are stored for entry into the integration package. In EQIV, all initial values are defined

$$N = 1, 2, ..., NEQ.$$

The following sequential ordering scheme is used to define the location of each system state variable in the array Y.

Angular and linear rates about or along all of the free-coordinate vectors

$$THAD(N): N = 1, 2, \dots, NFER.$$

Generalized elastic coordinate rates for all modes of vibration

$$THAD(N)$$
: $N = NFER + 1, ..., NFER + NMODS$.

Angular rates for all variable-speed wheels

THADW(M); M defined by code word SMV.

Displacements about or along selected free-coordinate vectors

$$THA(SFR(N)); N = 1, 2, ..., NFRC.$$

Generalized elastic coordinates, all of them

$$THA(N)$$
; $N = NFER + 1, ..., NFER + NMODS$.

Angular position of selected wheels

$$THAW(SMA(M))$$
; $M = 1, 2, ..., NMOA$.

 Elements of the first two columns of each transformation matrix that is obtained by direction-cosine technique

XMC(I,J,M);
$$1 = 1, 2, 3$$

 $J = 1, 2$
M defined by code word SD.

Refer to subroutine listing for exact details if needed. For any particular problem, all computation carried out in EQIV can be outputted on the line printer by defining

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE TRAN

Numerical solution of the vector-dyadic equations of motion requires that the orientation of all body fixed-reference frames relative to each other and to the inertially fixed frame be obtainable. A minimal set of transformation matrices is the set that defines the relative orientation of each body fixed and inertially fixed reference frame to the frame of computation. These transformation matrices are evaluated in subroutine TRAN. The user need never interface with this subroutine.

As discussed in section "Data Input Subroutine INOPT," subsection 7, three kinematic methods for obtaining transformation matrices are available for the user. TRAN makes use of the data stored in the code words SD, SMAL, and SEU to determine the kinematic technique to be used for the computation of each respective transformation matrix.

The following variable, defined in table 1, is recomputed in subroutine TRAN. All other variables used have been previously defined. The programmer is referred to the comment cards inserted in TRAN, and the following, for detailed definitions:

[XMC(I,J,K)] - see section "Programmer's Guide to Subroutine TRNSIV."

In subroutine TRAN, which is entered four times per integration step, the elements of all transformation matrices that have time-varying coefficients are recomputed.

If direction-cosine techniques are used, the first two columns of the transformation matrix [XMC(I,J,K)], namely

$${XMC(1,1,K)}$$
 and ${XMC(1,2,K)}$

are computed by integration of direction-cosine rate equations. The third column

is computed in TRAN by a simple vector cross-product operation. No attempt is made to ensure that the resultant matrix is orthonormal.

The author is of the opinion that since it generally is impossible to determine which of the six integrated direction cosine parameters is contributing most strongly to any error buildup, it is also impossible to define an orthonormalization procedure which would be satisfactory for all possible situations. If orthonormalization of transformation matrices must be maintained to a high degree of accuracy, then Euler angle techniques should be called for in INOPT.

If Euler angles are used, the appropriate free coordinate vectors must be aligned with body fixed coordinate axes in the nominal zero displacement state. Euler angle techniques are used to obtain only the transformation matrix between pairs of contiguous bodies. The transformation matrix to the computing frame is obtained by an appropriate matrix multiplication. The same logic is used for the small-angle technique with the exception that the approximation

$$\theta_{\rm M} = \sin \theta_{\rm M}$$

is employed.

For any particular problem, all computation carried out in TRAN can be outputted on the line printer by defining

$$LTRAN = .TRUE.$$

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE TRANVO

The primary purpose of TRANVD is to transform to computing frame coordinates all body fixed vectors and tensors, which are used more than once in the evaluation of the equations of motion. The user need never interface with this subroutine.

The following variables defined in table 1 are recomputed each time TRANVD is called by DYN:

{CAC (1,K)}	{HMC (I,M)}		
{CBC (I,K)}	{QFC (I,M)}		
{FLAC (1, MN) }	{QLC (I,L)}		
{FLQC (I,MN)}	[XIC (1,J,K)]		

Each of the above variables is defined in the section "Programmers Guide to Subroutine VDIV." In subroutine TRANVD, which is entered four times per integration step, the transformation matrices evaluated in TRAN are used to obtain the components of each of the above body fixed vectors and tensors in computing frame coordinates. Only those that have time-varying components in the computing frame are recomputed; all others retain the initial value that was set in VDIV.

For any particular problem, all computation carried out in TRANVD can be outputted on the line printer by defining

LTRANV = .TRUE.

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE RATE

The primary purpose of subroutine RATE is to compute all linear and angular velocity vectors that will be required by the succeeding subroutines. The user need never interface with this subroutine.

In the coding of N-BOD2, all hinge points of the system are assumed to be either on rigid bodies or at node points of flexible bodies. Consequently, all rate-related effects associated with the deformation dependent motion of hinge points are identically equal to zero. That is, in Reference 2, equation 126, all elements of the partition φ_H^R , φ_W^R , and φ_H^T equal zero.

The following variables are defined in table 1 and recomputed each time subroutine RATE is called by DYN:

$$\{ROMC(I,K)\}\$$
 $\{COMC(I,K)\}\$

In Reference 1, equation 141, the partition that defines relative rate between contiguous bodies is

$$\{\widetilde{\omega}\}=|q|\{\dot{\theta}\}$$

In Reference 2, equation 126, it is

$$\{\widetilde{\omega}\}=\{\widetilde{\omega}\}+[\varphi_{\mu}^{R}]\{\widetilde{a}\}$$

where, by equation 133, Reference 2,

$$\{\circ\widetilde{\omega}\}=\{\alpha\}\{\dot{\theta}\}$$

and under the restrictions of N-BOD2

$$\left[\varphi_{H}^{R}\right] = \left[0\right]$$

The components, relative to the computing frame, of the NB1 vectors contained in the column matrix $\{\widetilde{\omega}\}$ are stored in the array ROMC according to the following storage convention:

Body K is a rigid or flexible body; K = 1, 2, ..., NBOD

$$\{\text{ROMC (I,K)}\} = \{\vec{\widetilde{\omega}}_{K}\}_{c} = \sum_{M \in (K,1)} \vec{\theta}_{M} \{\vec{q}_{M}\}_{c}$$

Body K is a point mass; K = 2, 3, ..., NBOD

$$\{\text{ROMC (I,K)}\}=\{\overset{\circ}{\vec{\alpha}_K}\}_c=\sum_{M \in K-1} \dot{\theta}_M\{\overset{\circ}{q}_M\}_c$$

 K = NB1 implies linear velocity of the center-of-mass of body 1 relative to inertial origin

$$\{\text{ROMC (I,K)}\}=\{\hat{\vec{\beta}}_{I}\}_{c}=\sum_{M \in K-1} \hat{\theta}_{M} \{\vec{q}_{M}\}_{c}$$

Note that by applying equation 134 of Reference 1, namely

$$\vec{\widetilde{\omega}}_{K} = \sum_{M \in K+1} \dot{\theta}_{M} \vec{q}_{M}$$

all trivial multiplications by zero called for by the matrix equation

$$\{\widetilde{\omega}\}=[q]\{\dot{\theta}\}$$

are circumvented.

The relative angular-rate vectors stored in the array ROMC are used to compute the inertial angular-rate vectors; the components of which, relative to the computing frame, are stored in the array FOMC. Making use of equation 37 of Reference 1, the following parameters are stored in the array FOMC:

Body K is a rigid or flexible body; K = 1, 2, ..., NBOD

$$\{ \text{FOMC } (1,K) \} = \{ \vec{\omega}_K \}_c = \sum_{i \in S_{0,K,1}} \{ \vec{\widetilde{\omega}}_i \}_c$$

 Body K is a point mass, since hinge point K-1 is at a node point on body JCON(K); K = 2, 3, ..., NBOD

$$\{FOMC(I,K)\} = \{\vec{\omega}_{J(K)}\}_c$$

K = NB!

$$\{FOMC(1,K)\} = \{ROMC(1,K)\}$$

The elements of this array FOMC are used primarily to compute gyroscopic cross-coupling loads.

The user may choose the frame of computation to be either the inertially fixed-reference frame or the body 1 fixed-reference frame. In Reference 1, pages 34 and 35, the angular rate of the body K fixed-reference relative to the computing frame is defined. The components of these vectors, relative to the computing frame, are stored in the array COMC; that is,

Body K is a rigid or flexible body; K = 1, 2, ..., NBOD

$$\{COMC(I,K)\} = \{c\vec{\omega}_K\}$$

Body K is a point mass; K = 2, 3, ..., NBOD

$$\{COMC(I,K)\} = \{_c \vec{\omega}_{J(K)}\}_c$$

 \bullet K = NB1

$$\{COMC(I,K)\}=\{ROMC(I,K)\}$$

The elements of this array COMC are used primarily in the evaluation of the direction cosine equations to be integrated.

In Reference 1, equation 136, differentiation of the relative angular-velocity vector yields

$$\dot{\widetilde{\omega}}_{K} = \sum_{\mathbf{M} \in K-1} \left[\ddot{\theta}_{\mathbf{M}} \ \vec{\mathbf{q}}_{\mathbf{M}} + \dot{\boldsymbol{\theta}}_{\mathbf{M}} \ \dot{\vec{\mathbf{q}}}_{\mathbf{M}} \right]$$

The second term reflects the fact that free-coordinate vectors are not inertially fixed. This term carries through the development and appears in the final partitioned matrix form of the equations of motion: Reference 1, equation 144; or Reference 2, equation 136; as

The elements of the column matrix are computed and stored in the array DOMC according to the following storage convention:

Body K is a rigid or flexible body; K = 1, 2, ..., NBOD

$$\{DOMC(I,K)\} = \sum_{M \in K,I} \dot{\theta}_M \{\dot{\vec{q}}_M\}_c$$

Body K is a point mass K = 2, 3, ..., NBOD or K = NB1;

$$\{DOMC(I,K)\} = \{0\}$$

The components of the vectors \vec{q}_M are needed only for the above computation and are not stored in COMMON; furthermore, only those having nonzero components are evaluated.

For any particular problem, all computation carried out in RATE can be outputted on the line printer by defining

on card 1 of the data deck.

In the coding of subroutine RATE, it should be noted that by use of the EQUIVALENCE statement the single subscript arrays EFOMC, EROMC, ECOMC, and EDOMC, are used interchangeably with the double subscript arrays FOMC, ROMC, COMC, and DOMC, respectively. This is done to optimize computation speed.

PROGRAMMER'S GUIDE TO SUBROUTINE XDY

The primary purpose of subroutine XDY is to compute all required hinge point to center-of-mass position vectors and all inertia and pseudo-inertia tensors. The user need never interface with this subroutine.

On the left-hand side of the system equations of motion given in Reference 1 by equation 144 and in Reference 2 by equation 136, the computation of numerous pseudo-inertia tensors is required. To compute these tensors, it is also required to compute the components of the position vectors which locate center-of-mass position relative to hinge points.

In TRANVD, the center-of-mass vector, hinge-point vector, and inertia tensor for each body of the system is computed. Once these vectors and tensors are determined, no distinction need be made between rigid and flexible bodies for the computation of inertia and pseudo-inertia tensors of nests of bodies. Consequently, equations 11 and 63 through 70 of Reference 1 may be applied to define the contents of the matrix of inertia tensors defined by the partition

[X]

in the equations of motion.

The following variables are defined in table 1 and computed in XDY:

In Reference 1, equation 11, hinge point to center-of-mass position vectors are defined by the equation

$$\vec{\gamma}_{K-1,L} = \sum_{\substack{i \in S \\ i \neq K}} \vec{\beta}_i + \vec{\alpha}_L$$

where

$$K = 1, 2, \dots, NBOD$$
 and $K \le L$

To conserve computer storage and eliminate a superfluous dimension, the integer function KTO, defined along with the other utility subroutines, is used to store the triangular matrix of vectors in a two-dimensional array. That is

$$\{GAM(I,KL)\} = \{\overrightarrow{\gamma}_{K-1,L}\}_{C}$$

where

$$KL = KTO(NB1, K-1, L)$$

In Reference 1, equations 63 through 70, the tensor in row K, column I, $I \ge K$, is defined by the equation that satisfies one of the following criteria:

1. $K \in S_R$, $I \in S_{K-1}$, $I \in S_R$

$$\mathbf{X}_{K,I} = \sum_{\substack{\lambda \in S_{I-1} \\ \lambda \notin S_{L}}} \Phi_{\lambda} + \sum_{\lambda \in S_{I-1}} G_{K-1,I-1}^{\lambda}$$

2. $K \in S_R$, $I \in S_{K-1}$, $I \in S_L$

$$X_{K,I} = - m_I \Gamma_{K-1,I}$$

3. K ∈ S_R, I ∉ S_{K-1}

$$X_{K,I} = 0$$

4. $K \in S_L$, I = K

$$X_{K,I} = m_I 1$$

5. K € S_L, I € S_{K-1}

$$\mathbf{X}_{K,I} = 0$$

6. $K \in S_R$, I = NB1

$$\mathbf{x}_{\mathbf{K},\mathbf{I}} = -\sum_{\lambda \in \mathbf{S}_{\mathbf{K},\mathbf{I}}} \mathbf{m}_{\lambda} \, \Gamma_{\mathbf{K}\cdot\mathbf{I},\lambda}$$

7. $K \in S_L$, I = NB1

$$X_{K,1} = m_K 1$$

8. K = NB1, I = NB1

$$X_{K,I} = \sum_{\lambda \in S_0} m_{\lambda} 1$$

where

$$\mathbf{G}_{\mathbf{K}-\mathbf{1},\mathbf{I}-\mathbf{1}}^{\lambda} \; = \; \mathbf{m}_{\lambda} \; \left[\left(\vec{\gamma}_{\mathbf{I}-\mathbf{1},\lambda} \, \cdot \, \vec{\gamma}_{\mathbf{K}-\mathbf{1},\lambda} \right) \; \mathbf{1} \; - \; \vec{\gamma}_{\mathbf{I}-\mathbf{1},\lambda} \; \vec{\gamma}_{\mathbf{K}-\mathbf{1},\lambda} \right]$$

$$\Gamma_{K-1,\lambda} = \mathcal{S}(\vec{\gamma}_{K-1,\lambda})$$

and

To conserve computer storage and eliminate a superfluous dimension, the integer function KT1, defined along with the other utility subroutines, is used to store the symmetric matrix of tensors in a three-dimensional array. That is

$$[XDIC(I, J, KI)] = \left[\mathbf{x}_{K,I}\right]_{c}$$

where

$$KI = KT1(NB1, K, I)$$

From symmetry

$$\left[\mathbf{x}_{1,K}\right]_{c} = \left[XDIC\left(1,J,KI\right)\right]^{T}$$

where post superscript T implies "transpose."

On the first pass through XDY, all elements of the arrays XDIC and GAM are computed. Thereafter, only those elements of the arrays that have time-varying components are recomputed. To do this, the integer arrays, defined by the code words SPI, SVD, and SXT, are used.

For any particular problem, all computation carried out in XDY can be outputted on the line printer by defining

$$LXDY = .TRUE.$$

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE ETA

The primary purpose of subroutine ETA is to compute the forces and torques associated with the gyroscopic motion of each body and each nest of coupled bodies. The user need never interface with this subroutine.

On the right-hand side of equation 112 of Reference 2, the matrix

contains all gyroscopic forces and torques that enter into the coupled body equations of motion. The vector elements of this matrix are defined by the terms appearing in equations 107 and 108 of Reference 2. For the case of coupled rigid bodies, these terms reduce to those defined in Reference 1 by the partitions

$$\{\eta^c\}$$
 and $\{\eta^I\}$

of equation 88.

Subroutine ETA is programmed to avoid redundant and trivial computations. The integer code words SCN, SCR, SIX, SMC, SFLX, SFXM, SSCN, and SSIX are used to pick out exactly which bodies contribute significantly in each step of the computation. Only non-zero time-varying contributions are computed.

The following variables are defined in table 1 and computed in ETA:

$\{ETIC(I,K)\}$	$\{FLCRC(I,K)\}$
$\{CNF(I,K)\}$	$\{ETMC(I,M)\}$
FLIRC(I,K)	$\{ETC(1,K)\}$

The gyroscopic torque acting on the nest K-1, which consists of at least one rigid body, is from Reference 2, equation 107

$$-\sum_{\lambda \in S_{K-1}} \left[\mathring{\Phi}_{\lambda} \cdot \vec{\omega}_{\lambda} + \vec{\omega}_{\lambda} \times \vec{L}_{\lambda,\lambda} + \vec{\gamma}_{K-1,\lambda} \times \vec{C}_{\lambda} \right]$$

where

$$\vec{L}_{\lambda,\lambda} = \Phi_{\lambda} \cdot \vec{\omega}_{\lambda} + \vec{\Delta} \vec{L}_{\lambda,\lambda} + \sum_{\substack{M : \\ MO(M) = \lambda}} \vec{\tilde{H}}_{M}$$

$$\vec{\Delta} \vec{L}_{\lambda,\lambda} = \sum_{N,\lambda} \vec{Q}_{N,\lambda} \dot{a}_{N,\lambda} (t)$$

$$\vec{\Phi}_{\lambda} = \sum_{N,\lambda} \vec{E}_{N,\lambda} \dot{a}_{N,\lambda} (t)$$

$$\vec{C}_{\lambda} = m_{\lambda} \left[\sum_{\substack{i \in S_{0}, \lambda-1 \\ i \neq 1}} \left(\vec{\omega}_{J(i)} \times (\vec{\omega}_{J(i)} \times \vec{\beta}_{i}) + 2\vec{\omega}_{J(i)} \times \vec{\beta}_{i} \right) + \vec{\omega}_{\lambda} \times (\vec{\omega}_{\lambda} \times \vec{\alpha}_{\lambda}) + 2\vec{\omega}_{\lambda} \times \vec{\alpha}_{\lambda} \right]$$

$$(In N-BOD2 all \vec{\beta}_{i} assumed zero)$$

The gyroscopic force acting on the nest L-1, which consists of the point mass defined as body L, is from Reference 2, equation 108

and from the same equation, the gyroscopic force acting on the composite system is

$$-\sum_{\lambda \in S_0} \vec{C}_{\lambda}$$

These resultant quantities are computed and stored in the array ETC, so that

{ETC(I,K)} = components of the gyroscopic load vector, in computing frame coordinates, acting on the nest K-1; K = 1, 2, ..., NBOD.

{ETC(I,NBI)} = components of the gyroscopic force vector, in computing frame coordinates, acting on the composite system.

The following procedure is used to compute the elements of the array ETC:

1. For all bodies L contained in the set defined by the code word SSIX, compute

$$\left\{ \text{ETIC} \left(\mathbf{I}, \mathbf{L} \right) \right\} = \left\{ \vec{\omega}_{\mathbf{L}} \times \left(\Phi_{\mathbf{L}} \cdot \vec{\omega}_{\mathbf{L}} \right) \right\}_{\mathbf{C}}$$

2. For all bodies L contained in the set defined by the code word SSCN, compute

$$\left\{ \text{CNF} \left(\mathbf{I}, \mathbf{L} \right) \right\} = \left\{ m_{\mathbf{L}} \left[\sum_{\substack{i \in \mathbf{S}_{0, \mathbf{L} - 1} \\ i \neq 1}} \vec{\omega}_{\mathbf{J}(i)} \times (\vec{\omega}_{\mathbf{J}(i)} \times \vec{\beta}_{i}) + \vec{\omega}_{\mathbf{L}} \times (\vec{\omega}_{\mathbf{L}} \times \vec{\alpha}_{\mathbf{L}}) \right] \right\}_{c}$$

For all flexible bodies L, that is, for those bodies contained in the set defined by the integer code word SFLX, compute

$$\begin{aligned} \left\{ \text{FLIRC} \left(\mathbf{I}, \mathbf{L} \right) \right\} &= \left\{ \mathbf{\mathring{\Phi}}_{L} \cdot \vec{\omega}_{L} + \vec{\omega}_{L} \times \vec{\Delta L}_{L, L} \right\}_{c} \\ &= \left\{ \left[\sum_{\mathbf{N}, L} \left(\mathbf{E}_{\mathbf{N}, L} + \mathcal{S}(\vec{Q}_{\mathbf{N}, L}) \right) \dot{\mathbf{a}}_{\mathbf{N}, L} \left(t \right) \right] \cdot \vec{\omega}_{L} \right\}_{c} \\ \left\{ \text{FLCRC} \left(\mathbf{I}, L \right) \right\} &= \left\{ 2 m_{L} \vec{\omega}_{L} \times \overset{\circ}{\vec{\alpha}}_{L} \right\}_{c} \\ &= \left\{ 2 m_{L} \vec{\omega}_{L} \times \sum_{\mathbf{N}, L} \dot{\mathbf{a}}_{\mathbf{N}, L} \left(t \right) \vec{\mathbf{A}}_{\mathbf{N}, L} \right\}_{c} \end{aligned}$$

 Add gyroscopic loads associated with rigid body motion to that associated with relative elastic deformation to obtain

$$\left\{ \text{ETIC}\left(I,L\right)\right\} = \left\{ \text{ETIC}\left(I,L\right)\right\} + \left\{ \text{FLIRC}\left(I,L\right)\right\}$$

$$\left\{ \text{CNF}\left(I,L\right)\right\} = \left\{ \text{CNF}\left(I,L\right)\right\} + \left\{ \text{FLCRC}\left(I,L\right)\right\}$$

for each flexible body L.

5. For each symmetric wheel of the system, compute

$$\left\{ \mathsf{ETMC}\left(\mathsf{I},\mathsf{M}\right)\right\} = \left\{ \overrightarrow{\omega}_{\mathsf{MO}(\mathsf{M})} \times \overrightarrow{\widetilde{\mathsf{H}}}_{\mathsf{M}} \right\}_{\mathsf{C}}$$

- 6. Sum the gyroscopic loads associated with each body L contained in the nest K-1 to obtain the components of the gyroscopic load external to the nest K-1; K = 1, 2, ..., NBOD+1, as follows:
 - a. Initialize the array ETC:

$$\left\{ \text{ETC (I,K)} \right\} = \left\{ 0 \right\}; \qquad K = 1, 2, \dots, NB1$$

b. Add inertia cross-coupling terms for all bodies L contained in the set defined by the code word SIX(K-1):

$$\{ETC(I,K)\} = \{ETC(I,K)\} - \sum_{L \in SIX(K-1)} \{ETIC(I,L)\}$$

where

$$K = 1, 2, \ldots, NBOD$$

- Add centripetal cross-coupling terms for all bodies L contained in the set defined by the code word SCN(K-1):
 - If body L is a rigid or flexible body

$$\{CNF(I,L)\} = \{\vec{C}_L\}_c$$

If body L is a point mass

$$\left\{ \text{CNF} \left(\mathbf{I}, \mathbf{L} \right) \right\} = \left\{ \vec{\mathbf{C}}_{L} - 2m_{L} \vec{\omega}_{L} \times \hat{\vec{\alpha}}_{L} \right\}$$

Let

$$\{CNF(I,L)\}=\left\{\overrightarrow{C}_{L}\right\}_{C}$$

then, for all nests K-1 containing one or more rigid bodies

$$\left\{ \text{ETC}\left(\mathbf{I},\mathbf{K}\right)\right\} = \left\{ \text{ETC}\left(\mathbf{I},\mathbf{K}\right)\right\} - \sum_{\mathbf{I} \in \text{SCN}(K,L)} \left\{ \overrightarrow{\gamma}_{K-1,L} \times \overrightarrow{C}_{L}^{\star} \right\}_{c}$$

and for all nests K-1 containing the single-point mass labeled body K

$$\{\text{ETC}(I,K)\} = \{\text{ETC}(I,K)\} - \{\overrightarrow{\gamma}_{K-1,K} \times \overrightarrow{C}_{K}^*\}$$

and for K = NB1

$$\{\text{ETC}(I, K)\} = \{\text{ETC}(I, K)\} - \sum_{L=1}^{NBOD} \left\{\vec{C}_{L}^{\bullet}\right\}_{c}$$

d. Add Coriolis cross-coupling terms for all point masses (bodies L) contained in the set defined by the code word SCR(K-1):

For all nests K-1 containing one or more rigid bodies

$$\left\{ \text{ETC}\left(\mathbf{I},\mathbf{K}\right)\right\} = \left\{ \text{ETC}\left(\mathbf{I},\mathbf{K}\right)\right\} - \sum_{\mathbf{L} \in \text{SCR}\left(\mathbf{K}-\mathbf{I}\right)} \left\{ \overrightarrow{\boldsymbol{\gamma}}_{\mathbf{K}-\mathbf{I},\mathbf{L}} \times 2m_{\mathbf{L}} \overrightarrow{\boldsymbol{\omega}}_{\mathbf{L}} \times \overrightarrow{\boldsymbol{\alpha}}_{\mathbf{L}} \right\}_{\mathbf{c}}$$

For all nests K-1 containing the single-point mass labeled body K

$$\left\{ \text{ETC}\left(\mathbf{I},\mathbf{K}\right) = \left\{ \text{ETC}\left(\mathbf{I},\mathbf{K}\right) \right\} - \left\{ 2m_{\mathbf{K}} \vec{\omega}_{\mathbf{K}} \times \hat{\vec{\alpha}}_{\mathbf{K}} \right\}_{c}$$

and for K = NB1

$$\left\{ \text{ETC}\left(\mathbf{I},\mathbf{K}\right)\right\} \ = \ \left\{ \text{ETC}\left(\mathbf{I},\mathbf{K}\right)\right\} \ - \ \sum_{\mathbf{L}\in\mathbf{SL}} \left\{ 2m_{\mathbf{L}} \ \overrightarrow{\omega}_{\mathbf{L}} \times \overset{\circ}{\overrightarrow{\alpha}}_{\mathbf{L}} \right\}_{\mathbf{c}}$$

where SL is the code word defining all point-mass body labels.

e. Add symmetric wheel cross-coupling terms for all wheels M contained in the set defined by the code word SMC(K-1):

$$\{ETC(I,K)\} = \{ETC(I,K)\} - \sum_{M \in SMC(K-1)} \{ETMC(I,M)\}$$

where

$$K = 1, 2, \ldots, NBOD$$

For any particular problem, all computation carried out in ETA can be outputted on the line printer by defining

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE TORQUE

The primary purpose of subroutine TORQUE is to provide a place for the user to define the nongyroscopic forces and torques acting on the particular problem under investigation. In Reference 1, pages 41 through 53, several nongyroscopic effects commonly encountered in the analysis of spacecraft attitude dynamics are described along with the methods that must be used to enter their resultant effects into the equations of motion. This section will define the coding (by example) that is required to interface with N-BOD2.

The following variables are defined in table 1 and computed by user defined algorithms in TORQUE:

In subroutine TORQUE, the user has access to all computed system state variables. These are stored in the various labeled common blocks. Any user-defined function of state variables may be computed and stored in array DUMMY in labeled common block /SATELL/.

The nested body approach has been used to derive the equations of motion presented in References 1 and 2. In Reference 1, equation 88, the forces and torques acting external to the nests are contained in the partitions

$$\left|\phi^{H_1}\right| + \left|\phi^{E_1}\right|$$

while torques acting external to symmetric wheels are contained in the partition

In Reference 2, equation 111, the forces and torques acting external to the nests are contained in the partition

while torques acting external to symmetric wheels are contained in the partition

The user must define the algorithm that is to be used to compute

Frequently the algorithm involves the integration of differential equations such as in the description of an onboard control system. The user must define

NTQ - total number of differential equations that are defined by the user in TORQUE and which must be integrated.

The state variables and associated time derivatives for all first order differential equations defined in TORQUE are stored in the arrays Y and YD.

Let

$$N = NEQ + M$$

where

$$M = 1, 2, ..., NTQ$$

then

Y(N) = storage location to the state variables associated with the Mth differential equation defined by the user in TORQUE.

YD(N) = storage location of the time derivative of the state variable stored in Y(N).

To code subroutine TORQUE, the user should first zero out the external torque matrix upon entry. The resultant torque matrix is then obtained by vector addition of the various components. Thus, the first executable statements of TORQUE should be

^{*} Force if body K in nest K-1 is a point mass.

Motion about or along any free coordinate vector may be constrained by springs, dashpots, or motors. The computation of the associated reaction loads and their inclusion into the equations of motion are discussed in Reference 1, pages 42 through 45. The following coding is to be used to include these effects in N-BOD2:

```
REACTION TORQUE ACTING ACROSS OR ALONG GIRRAL AXIS M
                                                             AT MINGE POINT 4-1 CHE TO :
                                                               LINEAR SPRINGS
                                                              LINEAR VISCOUS NAMPERS
                                                               motoes.
  SPREM1 + SPRING CONSTANT ABOUT OH BEING GIMHAL BRIS M
(Met==2/1==2 Dx M/1==2)

DPC(=) = DAMP[NG CONSTANT ABOUT OR ALONG GIMHAL AXIS =
                                             ( MeL ** 2/1 08 M/1)
CLICHT - CONTROL TORQUE APPLIED BY MOTOR ABOUT OR ALONG GIMNAL AXIS M MHL-92/T-92 DR MHL/T-92
                                                                          DIMENSION TEMES!
                                                                           SPRING TORQUE
SPRINI & USER INPUT
                                                                           CALL SCLVER-OFC (1.*1.76*)
                                                                        CALL VECSUBIPHILLALITER.PHILLALI
                                                                       DAMPER TORQUE
                                                                       DPC(#) + USER TWPUT
                                                                           CALL SCLVIA-OFCII.*1.TE*1
                                                                       CALL VECSUMIFMILL, ... TEM, POSILL, ...
                                                                       CLTIME & FUNCTION OF STATE VARIANCES. USER DEF.
                                                 C
                                                                        CALL SCLVICETIMI . GET 11. #1. 10#1
                                                                         CALL VECADDIDUDISTANTATION OF THE PROPERTY OF
```

Symmetric wheels are usually used to simulate controlled momentum wheels. Since wheels have only one degree of freedom, it is not necessary to compute wheel torque as a vector quantity. The following coding is to be used to include this effect in N-BOD2:

```
C COMMENT & USER DEFINED EVECTION OF STATE VARIABLES

C COMMENT OF STATE VARIABLES (MPC##2/T**2)
```

Locally applied forces may be applied to any body of the system; they may not be applied to symmetric wheels directly. The computation of the reaction loads and their inclusion into the equations of motion are discussed in Reference 1, page 45. The following coding is used to include this effect in N-BOD2:

```
C
                 DIMENSION #JC(3).FJC(3).TEM(3).TEM1(3).#J(3).#J(3).FJ(3)
                 INTEGER STITIOTANST
                LOGICAL CTAIN
E
         (C
                 CALL VECTON(#J.XMC(1-1-1)-#JC)
FJ(1) = USER DEFINED FUNCTION OF STATE VARIANCES
CALL VECTON(FJ.XMC(1-1-1)-FJC)
                 CALL VECADDIPHI(1,NR1).FJC.PHI(1,NH1))
DO 3 K-1,NR0D
                         K = 1.NBOD
                 CALL UNPACISIONSIOSKIK-111
                 1F(.NOT.CTAIN(L.S1.NS1)) GO TO 3
                 CALL VECADDIPHILL.KI.FJC.PHILL.KII
                 GD TO 3
              CALL VECADDIGAM(1.KL).RJC.7FM)
                 CALL VECROS (TEM.F.IC.TEM)
                 CALL VECADDIPHILL . KI. TEMI, PHILL . KII
               3 CONTINUE
```

The system to be modeled may be in a gravitational field; i.e., an Earth-based system. The computation of the reaction loads and their inclusion into the equations of motion are discussed in Reference 1, pages 45 and 46. The following coding is used to include this effect in N-BOD2:

```
REACTION TORONES ON SYSTEM DUE TH GRAVITATIONAL
              EFFECTS ON AN EARTH MASED SYSTEM
CHAY - ACCELERATION OF GRAVITY (1/1007)
MHILL A COMPONENTS OF UNIT VECTOR FROM INSATIAL DRIGIN TO COMP.
         SYSTEM CENTER OF MASS, INCLATIVE TO INCUTTAL FRAME!
        THAT IS. PARALLEL TO DIRECTION OF GRAVITY FORCE
      1%1666# 51/101.951
      DIMENSION TEREST. HHC ($1.8H(5)
      RME [ 1 . LISER INPUT
      CALL VECTABLISH, EMCEL-1-01-8MC |
DO & KOLANDO
GRAV = USER INPUT
      ( & L L SC L V ( & . MM ( . 15 M ) ) . TEM . FOR [ 1 ] . NA [ 1 ] . TEM . FOR [ 1 ] . NA [ 1 ] .
      CALL VECSORIPHICS, *1.76* PHILLETS GO TO 4
    4 CACL UNPACISIASIASIASIA
      00 4 (1:1:15)
        . 511111
       ML . MTO: WAL. 4-1.L!
       A . EMASILIAGRAY
      CALL SCEVIA, AMC. TEM!
CALL VECKOS (GAM!), ALI. T. 16M1!
            VECSURIPMILLATINE PRICES
    A CONTINUE
```

The system to be modeled may be in orbit and subject to gravity gradient effects. The computation of the orbit and the gravity gradient torques are discussed in Reference 1, pages 46 through 52. The following coding is used to include these effects in N-BOD2:

```
REPLEATING COMPONENTS OF VECTOR FARTH'S CENTER TO COMPOSITE
C CHILO) • COMPONENTS OF VECTOR FARTH'S CENTER TO COMPOSITE
C SYSTEM CENTER OF MASS. RELATIVE TO INERTIAL MEFERENCE
FRAME. ORRIT ASSUMED TO BE IN INERTIAL 2-3 PLANE
C ASM • SEMI-MAJON AXIS OF ELLIPTIC GRRIT INERTIAL 2 DIMECTION
C COMMIT ECCENTRICITY
C TOP • TIME OF PERIMELION PASSAGE. (1)
C GEV • EARTM'S GRAVITATIONAL CONSTANT. (L**3/1**2)
C ETE • MEAN MOTION
C AME • MEAN ANDMALY
```

```
C
               ECE . ECCE. "RIC ANDMALY
C
               TVE . TRUE ANDRALY
               STO . MAGNITUDE OF CHIL.OI. IL
C
c
                    ASM . USER INPUT
GEV . USER INPUT
C
            C
c
                    ETE . 1./SORTIASMONS/GEVI
            c
                    TPP . USER INPUT
C
                    AME . ETE-(T-TPP)
C
                    SM1 . SIN(AME)
SM2 . SIN(2*AME)
                                            : SM4 = SIN(4*AME)
c
                    SM3 . SINI 3.AME
                    C
c
                           *ECC****(9*SM) - 3*SM11/(24)
*ECC***(64*SM4 - 32*SM2)/192
C
C
                    CE . COSTECET
C
                    SE . SINIECE!
BTO . ASH-11 - ECC-CE!
C
                   CB(1.0) = 0

CB(2.0) = BTO*((CE- ECC)/(1 - ECC*CE))

CB(3.0) = BTO*(SQRT(1-ECC*2)*SE/(1-ECC*CE))
C
C
C
                    CALL VECTRN(CR(1.0).XMC(1.1.0).CRC(1.0))
C
C
                           REACTION TORQUES ON DRAITING SYSTEM DUE TO
C
                                  GRAVITY GRADIENT EFFECTS
C
        CACITALL . COMPONENTS OF VECTOR FROM COMPOSITE SYSTEM CENTER OF
                       MASS TO CENTER OF MASS OF MODY 1. RELATIVE TO
                       COMPUTING FRAME
       . NOTE FOR GRAVITY GRADIENT OPTION

    ORTE FOR GRAVITY GRADIENT OFTION
    CRII.1) AND ITS INERTIAL DERIVATIVE
    ARE REDEFINED TO CIRCUMVENT DIFFERENCE
    OF LARGE NUMBER PROBLEMS, THAT IS
    THEY ARE REASURED FROM COMPOSITE CM TO
C
      . CM OF RODY I NATHER THAN FROM INSERTIAL ORIGIN TO CM OF RODY I
C
            AHIII . UNIT VECTOR FROM EARTH'S CENTER TO SYSTEM COMPOSITE
       CENTER OF MASS. COMPONENTS RELATIVE TO INERTIAL FRAME
DFL(I.K) - COMPONENTS OF VECTOR FROM COMPOSITE SYSTEM CENTER OF
MASS TO CENTER OF MASS OF RODY &

DFG(I.K) - COMPONENTS OF GRAVITY GRADIENT FORCE ACTING ON HODY R

SGG(I) - COMPACTED INTEGER WORD. THOSE HODIES IN THE NEST I
C
                       WHICH SIGNIFICANTLY CONTRIBUTE TO GRAVITY GRADIENT EFF.
               BTO . DISTANCE FROM EARTH'S CENTER TO COMPOSITE SYSTEM CM
                    DIMENSION DEL(3.10).DFG(3.10).BMC(3).BM(3).TEM(3).TEM(13)
                    INTEGER 5GG10.9). 51(10)
KEPLERIAN ORBIT MUST BE USED WITH GRAVITY GRADIENT OPTION
           C
                00 10 1-1.3
10 8HC(1) - CBC(1.01/810
                    00 7 K+1.NB00
                    KL . KTOINBI.O.K
                    CALL VECADDICACIA.II.GAMIL.KLI.DELIL.KII
                    CALL VECDOTIBHC.DEL([.KI.A)
                     CALL SCLVIA. MHC . TEM!
                    CALL VECSUBIDEL (1.4).TEM.TEMI
                    A . -GEVERMASIKI/RTO...
                  CALL SCLVIA. TER. OFGILED
0
                    00 8 8 1 . 5000
                     IFIRELDIKE GO TO 9
€
                    CALL VECADDIPHILL. KI. DEGIL. KI. PHILL. KII
                    GO TO A
                    SGG(1) . SR(1) IF ALL BODIES CONTRIBUTE TO GRAVITY GRAD.
                                         EFFECTS. IF NOT USE COMPAC TO CONSTRUCT
SGG(1) FORM USER INPUT OR DEFINE DIRECTLY
C
                  G CALL UNPACISTINST. SGG(K-1))
                    00 8 LL-1.451
C
                    L . SIILLI
                    KL . KTOINBI.K-1.LT
                    CALL VECROS (GAMII.KL).DFG(1.L).TEM)
                    CALL VEDYOVERHC. RICELLISTERIS
C
                    A . 3.GEV/RTO...
                    CALL SCLVEA. TEM1. TEM1)
CALL VECADDITEM. TEM1. TEM1
c
                 CALL VECADDIPHICIANITEM. PHICIANIA CONTINUE
```

As previously mentioned, it is often necessary to integrate several differential equations to define control torques in TORQUE. The following coding is used to include additional differential equations for integration by N-BOD2 along with the system equations:

```
PARAMETERS DEFINED BY FIRST ORDER
                             DIFFERENTIAL EQUATIONS
              NTO . TOTAL NUMBER OF FIRST ORDER DIFFERENTIAL EQUATIONS TO
C
           BE SOLVED FOR USE IN SUBROUTINE TORQUE
TO(N) = MAGNITUDE OF PARAMETER NUMBER N DEFINED WITHIN SUB.
TORQUE AT TIME T
C
C
          TODIN) - TIME DERIVATIVE OF PARAMETER TOIN). A USER DEFINED FUNCTION OF THE SYSTEM'S STATE VARIABLES
€
C
                                 DIMENSION T0(20). T00(20)
                        C
                                 FOR THE PARAMETER N
C
                                 1F1CT4.NE.11 GO TO 11
C
                         0
                            Y(NEO+N) . TO(N) : INITIAL VALUE FOR TO(N)
11 TO(N) = Y(NEO+N)
C
                                 TUDIN) . USER CEFINED FUNCTION OF STATE VARB.
                              AFTER DEFINITION OF LAST DIFFERENTIAL EQUATION NTO = TOTAL NUMBER OF FIRST ORDER DIFFERENTIAL
€
                               EQUATIONS TO BE SOLVED FOR USE IN TORQUE
DO 12 N=1.NTO
C
                            12 YOUNEQ+NI . TODINI
```

At times, appendages on spacecraft are subject to thermally induced motion. This is discussed in Reference 1, pages 52 and 53. The following coding is used to include this effect in N-BOD2:

```
C
                              THERMALLY INDUCED MOTION ABOUT GIRBAL AXIS H
                                 AT HINGE POINT K-1
        ASSUME:
                 ALL THERMALLY INDUCED DEFLECTION IS SMALL ANGLE
RELATIVE TO THE SYSTEM'S NOMINAL ZERO STRESS STATE
THERMALLY INDUCED DEFLECTION IS MODELLED AS A MOVEMENT
OF THE ZERO STRESS STATE
C
                   ACROSS ALL HINGE POINTS SUBJECT TO THERMAL DEFORMATION SPRINGS AND DAMPERS ACT
                   A RESONABLE MODEL OF THE THERMAL INPUT CAN BE DEFINED
IN TERMS OF THE SYSTEM'S STATE VARIABLES
THERMAL EQUILIBRIUM POSITION ABOUT ANY GIMBAL AXIS IS DEF.
                       BY SOLUTION OF THE HEAT CONDUCTION EQUATION
             SPRIMI . SPRING CONSTANT ACROSS GIMBAL AXIS M
             DPC(M) = DAMPING CONSTANT ACROSS GIMRAL AXIS M
TAU(M) = THERMAL TIME CONSTANT FOR DEFORMATION ABOUT GIMMAL
           AXIS M. (1)
TO(N) = THERMAL EQUILIBRIUM POSITION FOR THERMAL DEFORMATION
         ABOUT GIMBAL AXIS M. (RAD)

TOD(N) = RATE OF CHANGE OF THERMAL EQUILIBRIUM POSITION ABOUT

GIMBAL AXIS M. FIRST ORDER DIFF. EO.. (RAD/T)

TINP = THERMAL INPUT USER DEFINED FUNCTION OF STATE VARIABLES.
                       IRAD/TI
                     DIMENSION TEREST
                     N . USER DEFINED LAREL. DEPENDS UPON EQUATION NUMBERING
            0
                     SEQUENCE DEFINED WITHIN SURROUTINE TORQUE

[F(CT4.NE.]) GD TO 13

YINEQ+N) = TQIN) = INITIAL VALUE FOR THERMAL DEFORMATION
            0
            C
                                                 ABOUT GIMBAL AXIS M. USER INPUT
                13 TOINI . VINEO+NI
            r
                     TIMP . USER DEFINED THERMAL INPUT FOR THERMAL DEFORMATION
                              ABOUT GIMBAL AXIS M
                      TAUERI - USER INPUT
                     TODINI . - TOINI/TAUINI . TINE
                     A . SPR(M)*(THA(M) - TO(N))
                     CALL SCLVIA. OFCII.MI. TEMI
                     CALL VECSURIPHILI.KI.TEM.PHILI.KI)
                     A . DECIMINTHADINI
                     CALL SCLVIA. OFCII.MI. TEMI
                     CALL VECSURIPHICI. KI. TOM. PHICI. KII
```

For any particular problem, all computation carried out in TORQUE can be outputted on the line printer by defining

on card 1 of the data deck, if the user codes the print statements.

PROGRAMMER'S GUIDE TO SUBROUTINE QFDOT

The primary purpose of subroutine QFDOT is to eliminate the forces and torques associated with kinematic constraints. In so doing, the coupled vector-dyadic equations of motion will reduce to a set of simultaneous scalar differential equations. The user need never interface with this subroutine.

The equations of motion to be integrated are given in Reference 2 by equation 136. This equation, in the absence of body flexibility, reduces to equation 144 of Reference 1. Making use of the array names used in the coding of N-BOD2, the equation takes on the general form

$$[XMN] \{THADD\} = \{ETM\}$$

where, to be consistent with the coding of N-BOD2 and the notation of Reference 2,

$$\{\text{THADD}\} = \left\{\begin{array}{l} \ddot{\theta} \\ \vdots \\ \ddot{q}_{W} \end{array}\right\}$$

This matrix equation defines exactly

scalar second-order ordinary differential equations.

The following variables are defined in table 1 and computed in QFDOT:

The elements of these arrays are obtained by carrying out the vector-dyadic operations defined by the partitioned matrix equation 136 of Reference 2.

The equations coded in N-BOD2 assume that all hinge points and symmetric wheel attachment points are either on rigid bodies or at node points of flexible bodies. The restriction in modeling capability implies that in equation 136 of Reference 2, the following is true:

$$\varphi_{\mathbf{H}}^{\mathbf{R}} = 0,$$

$$\varphi_{\mathbf{W}}^{\mathbf{R}} = 0, \text{ and}$$

$$\varphi_{\mathbf{H}}^{\mathbf{T}} = 0$$

Furthermore, it is assumed in N-BOD2 that the user will not need to compute forces of constraint; that is, the elements of the partition F^c.

Introduction of these two modeling limitations significantly simplifies the required coding. The coding is structured so that, if required at a later date, both limitations can be removed by simple insertions into QFDOT and other relevant subroutines. Making use of the above assumptions, the equations coded in N-BOD2 are from equation 136 of Reference 2.

$$\begin{bmatrix} \mathbf{q}^{\mathsf{T}} & 0 & 0 \\ 0 & \mathbf{h}^{\mathsf{T}} & 0 \\ 0 & 0 & 1 \end{bmatrix} \bullet \begin{bmatrix} \mathbf{x} & \mathbf{i}^{\mathsf{c}} & \mathsf{F} \\ \mathbf{i}^{\mathsf{c}^{\mathsf{T}}} & \mathbf{i}^{\mathsf{s}} & 0 \\ \mathsf{F}^{\mathsf{T}} & 0 & \mathsf{M}^{\mathsf{I}} \end{bmatrix} \bullet \begin{bmatrix} \mathbf{q} & 0 & 0 \\ 0 & \mathbf{h} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \ddot{\theta} \\ \ddot{\theta}_{\mathsf{W}} \\ \ddot{a} \end{bmatrix} = \begin{bmatrix} \mathbf{q}^{\mathsf{T}} & 0 & 0 \\ 0 & \mathbf{h}^{\mathsf{T}} & 0 \\ 0 & 0 & 1 \end{bmatrix} \bullet \begin{bmatrix} \mathbf{x} & \mathbf{i}^{\mathsf{c}} & \mathsf{F} \\ \mathbf{i}^{\mathsf{c}^{\mathsf{T}}} & \mathbf{i}^{\mathsf{s}} & 0 \\ \mathsf{F}^{\mathsf{T}} & 0 & \mathsf{M}^{\mathsf{I}} \end{bmatrix} \bullet \begin{bmatrix} \dot{\mathbf{q}} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ \dot{\theta}_{\mathsf{W}} \\ \dot{a} \end{bmatrix} \bullet \begin{bmatrix} \eta_{1} \\ \eta_{2} \\ \eta_{3} \end{bmatrix} \bullet \begin{bmatrix} \phi^{(e)} \\ \mathsf{CL} \\ \eta_{3} \end{bmatrix}$$

Coding requirements force a rearrangement of rows and columns from that used in the theoretical development. The following storage allocation scheme is used:

•
$$[XMN (M, N)] = [q^T] \cdot [X] \cdot [q]$$

where $M = 1, ..., NFER$
 $N = 1, ..., NFER$

•
$$[XMN (M, N)] = [q^T] \cdot [F]$$

where
$$M = 1, \dots, NFER$$

$$N = NFER+1, ..., NFER+NMODS$$

•
$$[XMN(M, N)] = [q^T] \cdot [l^c] \cdot [h]$$

where
$$M = 1, ..., NFER$$

$$N = NFER+NMODS+1, ..., NFER+NMODS+NMV$$

•
$$[XMN (M, N)] = [M^1]$$

where
$$M = NFER+1, ..., NFER+NMODS$$

$$N = NFER+1, ..., NFER+NMODS$$

•
$$[XMN (M, N)] = [0]$$

where
$$M = NFER+1, ..., NFER+NMODS$$

$$N = NFER+NMODS+1, ..., NFER+NMODS+NMV$$

•
$$[XMN (M, N)] = [h^T] [l^s] [h]$$

where
$$M = NFER+NMODS+1, ..., NFER+NMODS+NMV$$

$$N = NFER+NMODS+1, ..., NFER+NMODS+NMV$$

•
$$\{\text{ETM }(M)\} = [q^T] \cdot \{\{\eta_1\} + \{\phi^{(e)}\} - [X] \cdot [\dot{q}] \{\dot{\theta}\}\}$$

where
$$M = 1, 2, \dots, NFER$$

•
$$\{\text{ETM (M)}\} = \{\eta_3\} - [F^T][\dot{q}]\{\dot{\theta}\}$$

where
$$M = NFER+1, ..., NFER +NMODS$$

•
$$\{ETM(M)\} = [h^T] \cdot \{\{\eta_2\} + \{CL\} - [i^{c^T}][\dot{q}] \{\dot{\theta}\}\}$$

where $M = NFER+NMODS+1, ..., NFER+NMODS+NMV$

In the computation of the ETM array, the contents of the ETC array defined in subroutine ETA are changed. In ETA, the components of the vector in row K of $\{\eta_1\}$ are stored in $\{ETC(1,K)\}$. In QFDOT, the components of the vector in row K of

$$\{\eta_i\}$$
 + $\{\phi^{(e)}\}$ - $[\mathbf{x}] \cdot [\dot{q}] \{\dot{\theta}\}$

are stored in $\{ETC(1,K)\}$.

In the computation of the full XMN array only the nontrivial entires of XMN are computed, and the lower triangular portion of the array is obtained by making use of the fact that the array must be symmetric. To ensure that all redundant and trivial operations are circumvented, the labels stored in the integer code words

are used extensively.

For any particular problem, all computation carried out in QFDOT can be outputted on the line printer by defining

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE DCT

The primary purpose of subroutine DCT is to set up the differential equations required to compute the elements of the transformation matrices that are to be obtained by direction cosine techniques. The user need never interface with this subroutine.

In Reference 1, equation 119, the direction cosine equation is given in a form compatible with this coupled body analysis; namely

$$\begin{bmatrix} c & \dot{\mathcal{F}}_{\lambda} \end{bmatrix} = -\mathcal{F}\left(\left\{c \vec{\omega}_{\lambda}\right\}\right) \begin{bmatrix} c & \mathcal{F}_{\lambda} \end{bmatrix}$$

N-BOD2 is coded to integrate only six of the nine equations defined for each transformation matrix that is to be derived by direction cosine techniques. The other three parameters of the respective transformation matrices are obtained in TRAN from orthogonality conditions.

The following array is defined in table 1 and the elements of it are computed in DCT:

In DCT, a unique numbering sequence is used to facilitate the handling of the direction cosine data. The body labels stored in the integer code word SD are obtained first. Let

 $\lambda_1, \lambda_2, \dots, \lambda_N$ = body labels associated with those body fixed-reference frames for which transformation matrices are to be obtained by direction cosine techniques

where

$$\lambda_1 > \lambda_2 > \ldots > \lambda_N$$
.

If $\lambda_N = 1$ and the body 1 fixed frame is the frame of computation, then to obtain the transformation matrix between inertial and body 1 coordinates.

$$\left\{ \mathbf{YMCD} \left(\mathbf{I}, \mathbf{1}, \mathbf{1} \right) \right\} = \begin{bmatrix} \mathbf{c} & \dot{\mathbf{F}}_{0} \end{bmatrix} \begin{pmatrix} \mathbf{1} \\ \mathbf{0} \\ \mathbf{0} \end{pmatrix}$$

$$\left\{ \mathbf{YMCD} \left(\mathbf{I}, \boldsymbol{\lambda}, \boldsymbol{1} \right) \right\} = \begin{bmatrix} \mathbf{x} & \mathbf{y} \\ \mathbf{x} & \mathbf{y} \end{bmatrix} \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

and for the rest, M = 1, 2, ..., N-1

$$\left\{ YMCD(1,1,M+1) \right\} = \begin{bmatrix} c \dot{\mathcal{F}}_{\lambda_{M}} \end{bmatrix} \begin{Bmatrix} 1 \\ 0 \\ 0 \end{Bmatrix}$$

$$\{YMCD(1, 2, M+1)\} = \begin{bmatrix} c \dot{\mathscr{F}}_{\lambda_{M}} \end{bmatrix} \begin{cases} 0 \\ 1 \\ 0 \end{cases}$$

Otherwise, for M = 1, 2, ..., N,

$$\{YMCD(1,1,M)\} = \left[\begin{matrix} \vdots \\ c \end{matrix} \right]_{M} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

$$\{YMCD(1,2,M)\} = \begin{bmatrix} \hat{\mathcal{F}}_{\lambda_M} \end{bmatrix} \begin{cases} 0 \\ 1 \\ 0 \end{cases}$$

For any particular problem, all computation carried in DCT can be outputted on the line printer by defining

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE ANGLE

The primary purpose of subroutine ANGLE is to set up the differential equations required to compute the displacement coordinates that are measured about or along the free coordinate vectors. The user need never interface with this subroutine.

The following array is defined in table 1 and the elements of it are computed in ANGLE:

In Reference 1, pages 37 and 38, the differential equations which define relative displacement about or along free coordinate vectors are defined. These equations are coded in

ANGLE. The user has the capability by subroutine INOPT to select which displacement coordinate should be evaluated. The integer array SFR defines the selected coordinates.

Several special cases are recognized in ANGLE:

If relative translational motion is measured along free coordinate vector

$$M = SFR(N)$$

then

$$ANGD(N) = THAD(M) = \dot{\theta}_{M}$$

(Point mass motion or body 1 center-of-mass motion.)

If free coordinate vector

$$M = SFR(N)$$

is aligned with the gimbal axis of a one-axis gimbal, then

$$ANGD(N) = THAD(M) = \dot{\theta}_M$$

If the free coordinate vectors

$$M = SFR(N)$$
 and

$$M+1 = SFR(N+1)$$

are aligned with the gimbal axes of a two-axis gimbal at hinge point K-1, then

$$C = \vec{q}_M \cdot \vec{q}_{M+1}$$

$$A_1 = \vec{q}_M \cdot \vec{\tilde{\omega}}_K$$

$$A_3 = \vec{q}_{M+1} \cdot \vec{\tilde{\omega}}_K$$

and

ANGD (N)
$$\approx \frac{A_1 - C \cdot A_3}{1 - C^2}$$

$$ANGD(N+1) = \frac{A_3 - C \cdot A_1}{1 - C^2}$$

If the free coordinate vectors

$$M + i = SFR(N + i)$$
 $i = 0, 1, 2$

are aligned with the gimbal axes of a three-axis gimbal at hinge point K-1, then

$$C = \vec{q}_{M} \cdot \vec{q}_{M+2}$$

$$A_{1} = \vec{q}_{M} \cdot \vec{\tilde{\omega}}_{K}$$

$$A_{2} = \vec{q}_{M+1} \cdot \vec{\tilde{\omega}}_{K}$$

$$A_{3} = \vec{q}_{M+2} \cdot \vec{\tilde{\omega}}_{K}$$

and

ANGD (N) =
$$\frac{A_1 - C \cdot A_3}{1 - C^2}$$

ANGD (N + 1) = A_2
ANGD (N + 2) = $\frac{A_3 - C \cdot A_1}{1 - C^2}$

For any particular problem, all computations carried out in ANGLE can be outputted on the line printer by defining

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINE SETUP

The primary purpose of SETUP is to provide the necessary interface between the symbolic array names used in the derivation of the equations of motion in N-BOD2 and the symbolic array names used in the integration subroutine RUNGE. The user need never interface with this subroutine.

The following sequential ordering scheme, used to define the locations of state variables and their time derivatives in the Y and YD arrays, is identical to that used in EQIV:

Accelerations and rates relative to free coordinate vectors

$$YD(N) = THADD(N)$$
; $THAD(N) = Y(N)$
 $N = 1, 2, ..., NFER$

Sum equations: NEQ = NFER

Accelerations and rates of generalized elastic coordinates

$$YD(N) = THADD(N)$$
 : $THAD(N) = Y(N)$
 $N = NEQ+1,...,NEQ+NMODS$

Sum equations: NEQ = NEQ+NMODS

Accelerations and rates of symmetric wheels with variable rate. Let

$$M_1, M_2, \dots, M_L$$
 = wheel labels in the set defined by integer code word SMV

$$YD(N) = THADD(N)$$
: $THADW(M_1) = Y(N)$
 $N = NEQ+1, ..., NEQ+L$
 $1 = 1, 2, ..., L$

Sum equations: NEQ = NEQ+L

Rate and displacement relative to free coordinate vectors

Sum equations: NEQ = NEQ+NFRC

Rate and displacement of generalized elastic coordinates

$$YD(N) = THAD(M)$$
 : $THA(M) = Y(N)$
 $N = NEQ+1, \dots, NEQ+NMODS$
 $M = 1, 2, \dots, NMODS$

Sum equations: NEQ = NEQ+NMODS

Rate and angle of symmetric wheels

Sum equations: NEQ = NEQ+NMODS

Rate and magnitude of direction cosine

K₁, K₂,..., K_{1D} = body labels associated with the coordinate frames for which transformation matrix is to be obtained via direction cosine

$$YD(N) = YMCD(I, J, M)$$
 $M = 1, 2, ..., ID$
 $J = 1, 2$
 $I = 1, 2, 3$
 $N = NEQ + 6 * (M - 1) + 3 * (J - 1) + 1$
 $XMC(I, J, K_M) = Y(N)$
 $I = 1, 2, 3$
 $J = 1, 2$
 $M = 1, 2, ..., ID$

The exact algorithm is obtainable in the discussion of subroutine DCT.

For any particular problem, all computations carried out in SETUP can be outputted on the line printer by defining

on card 1 of the data deck.

PROGRAMMER'S GUIDE TO SUBROUTINES OUTPUT AND OUTPSP

The primary purpose of subroutines OUTPUT and OUTPSP is to provide a convenient place to put all output data statements. OUTPUT is entered only at time zero while OUTPSP is entered at the end of every integration step unless otherwise directed by the user. The user is expected to refrain from modifying subroutine OUTPUT. It provides a useful echo of the initial state of the system for checkout purposes.

Nominally, subroutine OUTPSP is identical to OUTPUT. The user is expected to remove unwanted print statements from OUTPSP, add additional computation if desired, and insert any other set of desirable output statements.

The following parameters are outputted on the line printer by subroutine OUTPUT:

TIME - simulation time t

CENTER OF MASS — components of the vector from hinge point 0 to the center-ofmass of the composite system relative to the frame of computation

TOTAL SYSTEM MASS - total mass of the system

SYSTEM INERTIA TENSOR — components of the total system inertia tensor relative to the composite system center-of-mass and relative to the frame of computation

ANGULAR MOMENTUM — magnitude of the total system inertial angular momentum vector

HBODY — components of the total system inertial angular momentum vector relative to body 1 fixed coordinates

HINERT — components of the total system inertial angular momentum vector relative to inertial coordinates

LINEAR MOMENTUM — magnitude of the total system inertial linear momentum vector

LBODY — components of the total system inertial linear momentum vector in computing frame coordinates

KINETIC ENERGY - kinetic energy of total system

After the above parameters are printed, a block of data for each body of the system is printed:

BODY K = body label for the body for which the adjacent block of data applies; K = 1, 2, ..., NBOD

ROMC =
$$\{\text{ROMC}(1.K)\}$$
 = $\{\widetilde{\omega}_K\}_c$

FOMC =
$$\{\text{FOMC}(LK)\}=\{\omega_K\}_{C}$$

ACC = not in common =
$$\left\{ \vec{\omega}_{K} \right\}_{c}$$

$$CAC = \{CAC(I.K)\} = \{\vec{\alpha}_K\}_c$$

$$CBC \approx \{CBC(I.K)\} = \{\vec{\beta}_K\}_c$$

POS = not in common =
$$\{\vec{\gamma}_{l,K}\}_c$$

VEL = not in common =
$$\left\{ \overrightarrow{\gamma}_{l,K} \right\}_c$$

$$XMC = [XMC(1, J, K)] = [_c, \widehat{J}_K]$$

$$XIC = [XIC(1, J, K)] = [\Phi_K]$$

HB
$$\approx$$
 not in common $\approx \left\{ \vec{L}_{I,K} \right\}_{c}$

LM = not in common =
$$\left\{ \vec{G}_{L,K} \right\}_c$$

TK a not in common

$$\begin{split} & = \frac{1}{2} \left[\vec{\omega}_{K} + (\Phi_{\lambda} + \vec{\omega}_{K} + m_{K} \vec{\gamma}_{I,K} \times \dot{\vec{\gamma}}_{I,K}) \right. \\ & + m_{K} \dot{\vec{\gamma}}_{I,K} + \dot{\vec{\gamma}}_{I,K} + \sum_{\substack{M : \\ MO(M) = K}} \vec{\widetilde{\omega}}_{W_{M}} + \vec{\widetilde{H}}_{M} \right] \end{split}$$

The block of data pertinent to the translational motion of the center-of-mass of body 1 is given adjacent to the title, "ORIGIN."

FOMC =
$$\{\text{FOMC}(1, \text{NB1})\}$$
 = $\{\vec{\beta}_1\}$ c
ACC = not in common = $\{\vec{\beta}_1\}$ c
CBC = $\{\text{CBC}(1, 0)\}$ = $\{\vec{\beta}_0\}$ c
ETC = $\{\text{ETC}(1, \text{NB1})\}$ = See QFDOT
PHI = $\{\text{PHI}(1, \text{NB1})\}$ = See TORQUE
XMC = $\{\text{XMC}(1, J, 0)\}$ = $[c, \mathcal{F}_0]$

For each symmetric wheel of the system, the following data are outputted:

HMOM (M) =
$$|\vec{H}_{M}|$$

CLM (M) = $|\vec{CL}_{M}|$

For each flexible body of the system, a block of data associated with its flexible body characteristics is outputted:

FLEXIBLE BODY K - body label for the flexible body for which the adjacent block of data applies

$$\begin{split} & \text{EP} = \left\{ \vec{\Delta \alpha}_K \right\}_K = \sum_{N,K} \left\{ \vec{A}_{N,K} \right\}_K \vec{a}_{N,K} \left(t \right) \\ & \text{EPD} = \left\{ \vec{\hat{\alpha}}_K \right\}_C = \sum_{N,K} \left\{ \vec{A}_{N,K} \right\}_C \vec{a}_{N,K} \left(t \right) \\ & \text{QD} = \sum_{N,K} \left\{ \vec{Q}_{N,K} \right\}_K \vec{a}_{N,K} \left(t \right) \\ & \text{EI} = \sum_{N,K} \left[\mathbf{E}_{N,K} \right]_K \vec{a}_{N,K} \left(t \right) = \left[\Delta \Phi \right]_K \\ & \text{EID} = \sum_{N,K} \left[\mathbf{E}_{N,K} \right]_K \vec{a}_{N,K} \left(t \right) = \left[\vec{\Phi}_K \right]_K \\ & \text{FIR} = \left\{ \text{FLIRC} \left(\mathbf{I},K \right) \right\} = \text{See ETA} \end{split}$$

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FCR =
$$\left\{ FLCRC(I, K) \right\} = See ETA$$

$$\acute{D}HM = \sum_{N,K} \left\{ Q_{N,K} \right\}_{c} \dot{a}_{N,K}(t) = \left\{ \overrightarrow{\Delta L}_{\lambda,\lambda} \right\}_{c}$$

Following the last block of flexible body data, the system state variables associated with relative body motion and flexible body motion are printed:

For M = 1, 2, ..., NFER

$$THA(M) = \theta_{M}(t)$$

$$THAD(M) = \dot{\theta}_{M}(t)$$

$$THADD(M) = \ddot{\theta}_{M}(t)$$

$$QFC(M) = \{QFC(I, M)\}_{c} = \{\vec{q}_{M}\}_{c}$$

For MN = 1, 2, ..., NMODS and M = NFER+MN

THA (M) =
$$a_{N,K}(t)$$

THAD (M) =
$$\dot{a}_{N,K}(t)$$

THADD (M) =
$$\ddot{a}_{N,K}$$
 (t)

where

$$MN = N + \sum_{i=1}^{K-1} SFXM(i)$$

$$K = 2, 3, ..., NBOD$$

$$N = 1, 2, ..., SFXM(K) [See INOPT, subsection 15]$$

All of the above data will be printed at the end of each integration step. The user is expected to delete the undesired print statements from OUTPSP and to insert those more applicable to the problem at hand.

PROGRAMMER'S GUIDE TO THE UTILITY ROUTINES

The utility routines required by N-BOD2 are:

SIMQ — used to obtain the solution to a set of simultaneous linear equations of the form

$$[\times] \{\ddot{\theta}\} = \{\eta\}$$

A standard reduction technique is used to solve for $\{\ddot{\theta}\}$ without ever obtaining the inverse of the coefficient matrix.

RUNGE - used to numerically integrate the set of simultaneous nonlinear differential equations,

$$\{\dot{y}(t)\} = \{F(t)\}\$$

Fourth order, fixed-step Runge-Kutta integration is used.

COMPAC - used to create integer code words.

Integer code words are used primarily to conserve computer storage. This was a critical factor on the small XDS-9300 computer on which N-BOD2 was originally debugged.

Let

$$(I_1, I_2, \ldots, I_N)$$

be a set of unique integer labels so that

$$1 \le I_i \le 24$$
 ; $i = 1, 2, ..., N$

and

If computer storage is limited, it is a vaste of computer storage to reserve 24 words of memory to store this set.

All integer code words are 32 bits long.* These bits may be numbered as shown below:



^{*}IBM 360 Computer, subroutine must be modified for computers having different word lengths.

COMPAC stores the number of labels (N; $N \le 24$) in bits 25 through 32. The set of integers I_1, I_2, \ldots, I_N are stored in bits 1 through 24. For $J = 1, 2, \ldots, 24$, if bit J = 1, J is a member of the set; if bit J = 0, J is not a member of the set.

UNPAC - used to decode the integer code words created by COMPAC

KT0 and KT1 — integer function subprograms used to assign storage area locations in one-dimensional arrays for elements of triangular or symmetric matrices; another tool used to conserve storage requirements:

$$KTO(N, J, K) = \begin{cases} K(N-1) + J + 1 - K(K-1)/2 & K < J \\ J(N-1) + K + 1 - J(J-1)/2 & K \ge J \end{cases}$$

$$J = 0, 1, \dots, N-1$$

$$K = 0, 1, \dots, N-1$$

$$KT1 (N, J, K) = \begin{cases} (K-1) (N-1) + J - (K-1) (K-2)/2 & K < J \\ (J-1) (N-1) + K - (J-1) (J-2)/2 & K > J \end{cases}$$

$$J = 1, 2, \ldots, N$$

$$K = 1, 2, \ldots, N$$

CTAIN - logical function subprogram used to determine if a particular integer is contained in a particular set of integers

CTAIN (I, S, N) = .TRUE. if the integer I is contained in the set of integers S (1), S (2), ..., S (N)

= .FALSE. if it is not

VECTRN (VA, TBA, VB) - transform vectors

TENTRN (XA, TBA, XB) - transform dyads

$$[X]_{R} = [_{R} \mathcal{J}_{A}] [X]_{A} [_{R} \mathcal{J}_{A}]^{T}$$

- normalize vector to unit magnitude

$$\vec{\omega} = \frac{\vec{\mathbf{v}}}{|\vec{\mathbf{v}} \cdot \vec{\mathbf{v}}|^{6}}$$

$$\vec{v} = \vec{\omega}$$

Error message if $\vec{v} \cdot \vec{v} = 0$; inputted vector destroyed

MATMUL (A, B, C, N) - multiply two N X N matrices of scalars

$$[C] = [A] [B]$$

TRNSPS (TBA) - transpose a 3 × 3 matrix of scalars

$$[TEM] = [TBA]^T$$

$$[TBA] = [TEM]$$

Inputted matrix destroyed

ROT (A, J, T) - forms transformation matrix for rotation about a coordinate axis

A -- sine of the rotation angle

J - axis about which positive rotation is measured; J = +1, -1, +2, -2, +3 or -3 Define:

$$JJ = |J|$$

$$V_1 = 0$$

$$V_2 = 0$$

$$V_3 = 0$$

Redefine:

$$V_{IJ} = A*J/JJ$$

Then:

[T] =
$$\begin{bmatrix} \sqrt{1 - V_2^2 - V_3^2} & -V_3 & V_2 \\ V_3 & \sqrt{1 - V_1^2 - V_3^2} & -V_1 \\ -V_2 & V_1 & \sqrt{1 - V_1^2 - V_2^2} \end{bmatrix}$$

VECADD (V1, V2, S) - add vectors

$$\vec{S} = \vec{v}_1 + \vec{v}_2$$

VECSUB (V1, V2, D) - subtract vectors

$$\vec{D} = \vec{v}_1 - \vec{v}_2$$

SCLV (SC, V, P) – multiply vector by a scalar

$$\vec{P} = SC * \vec{v}$$

VECDOT (V1, V2, D) - vector dot product

$$D = \vec{v}_1 \cdot \vec{v}_2$$

VECROS (V1, V2, C) - vector cross product

$$\vec{c} = \vec{v}_1 \times \vec{v}_2$$

TRIPVP (V1, V2, V) - special triple vector product

$$\vec{v} = \vec{v}_1 \times (\vec{v}_1 \times \vec{v}_2)$$

DYADD (D1, D2, D) - add dyads

$$D = D_1 + D_2$$

SCLD (A, D, T) - multiply dyad by a scalar

$$T = A * D$$

$$\vec{D} = \mathbf{A} \cdot \vec{\mathbf{v}}$$

VXDYOV (V1, D, V) - special vector cross dyad dot vector

$$\vec{v} = \vec{v}_1 \times (D \cdot \vec{v}_1)$$

DYTOV (D, V1, V) - dyad transpose dot vector

$$\vec{v} = D^T \cdot \vec{v}_1$$

VODYOV (V1, D, V2, SC) - vector dot dyad dot vector equals scalar

$$SC = \vec{v}, (D \cdot \vec{v}_2)$$

DYOP (V, D) - skew operator

$$D = \mathcal{G}(\vec{v})$$

$$= \begin{bmatrix} 0 & v_3 & -v_2 \\ -v_3 & 0 & v_1 \\ v_2 & -v_1 & 0 \end{bmatrix}$$

SUEOP (V1, V2, XM, D) - construct pseudo-inertia tensors

$$D = m [(\vec{v}_1 \cdot \vec{v}_2) 1 - \vec{v}_2 \vec{v}_1]$$

QUTMUL (Q1, Q2, P) - multiply quaternions

$$\bar{p} = \bar{Q}_1 \cdot \bar{Q}_2$$

QUATOP (QF, THA, ZT) - construct rotation quaternion

$$\theta = THA$$

$$\{\vec{QF}\} = \begin{pmatrix} q_1 \\ q_2 \\ q_3 \end{pmatrix}$$

$$\{\overline{ZT}\} = \begin{cases} \cos \theta/2 \\ q_1 \sin \theta/2 \\ q_2 \sin \theta/2 \\ q_3 \sin \theta/2 \end{cases}$$

TRANSO (ZT, TAU) - construct transformation matrix from quaternion component

$$\{\overline{ZT}\} = \begin{cases} e_0 \\ e_1 \\ e_2 \\ e_3 \end{cases}$$

[TAU] =
$$\begin{bmatrix} e_0^2 + e_1^2 - e_2^2 - e_3^2 & 2(e_0 e_3 + e_1 e_2) & 2(e_1 e_3 - e_0 e_2) \\ 2(e_1 e_2 - e_0 e_3) & e_0^2 - e_1^2 + e_2^2 - e_3^2 & 2(e_2 e_3 + e_0 e_1) \\ 2(e_1 e_3 + e_0 e_2) & 2(e_2 e_3 - e_0 e_1) & e_0^2 - e_1^2 - e_2^2 + e_3^2 \end{bmatrix}$$

UNCAGE (SCG, SC, T, TUG) - check to see if it is time to uncage any of the caged degrees of freedom. If it is time, redefine SCG and SC.

COMPRS (XMN, THADD, N, SC, SCG, LG) — remove rows from XMN and THADD arrays and columns from XMN array associated with caged degrees of freedom, renumber and return compressed XMN and THADD arrays.

UNPRS (THADD, M, SCG, LG) - expand THADD array putting zeros in locations associated with caged degrees of freedom.

NOTATIONAL CROSS-REFERENCE

The equations of motion are derived in References 1 and 2 using standard analytic notation. They are programmed in N-BOD2 using FORTRAN IV notation and are outputted on the line printer using an abbreviated FORTRAN notation. This section is intended to provide the user with a notation cross-reference between the three techniques used to define and evaluate the equations of motion.

1. Matrix Notation

| - column matrix
 | - square matrix
 | - row or rectangular matrix

2. Vector-Tensor-Matrix Notation

Vectors and tensors must be stored relative to particular reference frames. A post subscript outside of the brace or bracket is used to specify the reference frame in which the vector or tensor is defined. For example,

 $\{\vec{V}_K\}_K$ - 3 × 1 column matrix of the components of the vector \vec{V}_K relative to body K fixed coordinates

 $\left[\mathbf{T}_{\mathbf{K}}\right]_{\mathbf{C}}$ - 3 × 3 square matrix of the components of the tensor $\mathbf{T}_{\mathbf{K}}$ relative to the frame of computation

If the elements of the vector \vec{V}_K are stored relative to the body K fixed-reference frame in the array VE and relative to the frame of computation in the array VEC,

where

DIMENSION VE (3, 10), VEC (3, 10),

the following notation is used:

Analytic Notation References 1 and 2	N-BOD2 FORTRAN IV Coding	N-BOD2 Users Manual	N-BOD2 Outputted Equations
$\{\vec{v}_{\kappa}\}_{\kappa}$	VE (1, K) VE (2, K) VE (3, K)	{VE (1,K)} _K	VE (K)
$\{\vec{v}_{\kappa}\}_{c}$	VEC (1, K) VEC (2, K) VEC (3, K)	{VEC (I,K)} _c	VEC (K)

3. Mathematical Operational Notation

In the output of the equations of motion, the analytic symbology used to define several mathematical operations cannot be duplicated with a standard line printer. The following notation has been adopted:

Let

define the dimension of the following quantities:

S1, S2, S3 — storage locations for the scalars S₁, S₂, S₃
 V1, V2, V3 — storage locations for the components of the vectors
 \(\frac{\frac{1}{3}}{\frac{1}{3}}, \frac{\frac{1}{3}}{\frac{1}{3}}, \frac{\frac{1}{3}}{\frac{1}{3}} \)
 = storage locations for the components of the tensors of rank two, dyads \(\frac{1}{1}, \frac{1}{2}, \frac{1}{3} \)
 Q1, Q2, Q3 — storage locations for the components of the quaternions \(\frac{1}{3}, \frac{1}{3}, \frac{1}{3}, \frac{1}{3} \)
 M1, M2, M3 — storage locations for the components of the 3 × 3 matrices of scalars \(\frac{1}{3}, \frac{1}{3}, \frac{1}{3}, \frac{1}{3} \)

The following cross-reference for mathematical operations is used in the output of equations of motion:

Addition

$$S_3 = S_1 + S_2$$
 $\approx S_3 = S_1 + S_2$
 $\vec{v}_3 = \vec{v}_1 + \vec{v}_2$ $\approx V_3 = V_1 + V_2$
 $T_3 = T_1 + T_2$ $\approx T_3 = T_1 + T_2$
 $[M_3] = [M_1] + [M_2] \approx M_3 = M_1 + M_2$

Subtraction

(Same as addition)

Division

$$S_3 = \frac{S_1}{S_2}$$
 \approx $S_3 = S_1/S_2$
 $\vec{v}_3 = \frac{1}{S_1} \vec{v}_1$ \approx $V_3 = V_1/S_1$
 $\vec{v}_3 = \frac{1}{S_1} \vec{v}_1$ \approx $T_3 = T_1/S_1$

Scalar Multiplication

$$S_3 = S_1 S_2 \approx S3 = S1 \cdot S2$$

 $\vec{v}_3 = S_1 \vec{v}_1 \approx V3 = S1 \cdot V1$
 $T_3 = S_1 T_1 \approx T3 = S1 \cdot T1$
 $[M_3] = S_1 [M_1] \approx M3 = S1 \cdot M1$

Quaternion Multiplication

$$\overline{Q}_3 = \overline{Q}_1 \overline{Q}_2 \approx Q3 = Q1 \cdot Q2$$

Scalar Product

$$S_1 = \overrightarrow{v}_1 \cdot \overrightarrow{v}_2 \approx S1 = V1 \cdot V2$$

 $\overrightarrow{v}_1 = \overrightarrow{T}_1 \cdot \overrightarrow{v}_2 \approx V1 = T1 \cdot V2$
 $\overrightarrow{v}_3 = \overrightarrow{v}_2 \cdot \overrightarrow{T}_1 \approx V3 = V2 \cdot T1$

Vector Product

$$\vec{v}_3 = \vec{v}_1 \times \vec{v}_2 \approx V3 = V1 \times V2$$

$$T_1 = \vec{v}_1 \times T_2 \approx T1 = V1 \times T2$$

$$T_3 = T_2 \times \vec{v}_1 \approx T3 = T2 \times V1$$

Tensor Product

$$T_1 = \vec{v}_1 \vec{v}_2 \approx T1 = V1 V2$$

Transpose Matrix

$$[M_2] = [M_1]^T \approx M_2 \approx M1 \cdot T$$

Transform Coordinates of Vectors and Tensors

If

[M,] - transformation matrix, reference frame A to reference frame B

V1, T1 − storage area for components of \overrightarrow{v}_1 and \overrightarrow{T}_1 relative to reference frame A respectively

V2, T2 - storage area for components of $\vec{v_1}$ and $\vec{T_1}$ relative to reference frame B respectively,

then

$$\left\{\vec{\mathbf{v}}_{i}\right\}_{B} = \left\{\mathbf{M}_{1}\right\}\left\{\vec{\mathbf{v}}_{i}\right\}_{A} \approx V2 = M1 \cdot V1$$

$$\left\{\mathbf{T}_{1}\right\}_{B} = \left\{\mathbf{M}_{1}\right\}\left\{\mathbf{T}_{i}\right\}_{A} \left\{\mathbf{M}_{1}\right\}^{T} \approx T2 = M1 \cdot T1 \cdot M1 \cdot T$$

Rotation Quarternion

Using the notation of Reference 1 (see equations 99, 100, 101, and A-21),

$$\overline{Q}_1 = \cos \frac{S_1}{2} + \mathcal{Q}\left(\left\{\overrightarrow{v}_1\right\}\right) \sin \frac{S_1}{2}$$

$$\approx$$
 Q1 = QUATOP (V1, S1)

Subroutine QUATOP makes use of the scalar S1 and the three elements stored in the array V1 to compute the four components of the quarternion Q1 (see Utility Routine/QUATOP).

Transformation Matrix from Rotation Quarternion

Using the notation of Reference 1 (see equations 96, 97, 98, and A-18),

$$[M_1] = \mathscr{F}(\overline{Q}_1)^T \approx M1 = TRANSO(Q1)$$

Subroutine TRANSO makes use of the four elements stored in the array Q1 to compute the components of the associated transformation matrix (see Utility Routine/TRANSO).

Transform Vectors to Tensors

Using the notation of Reference 1 (see equation 51),

$$T_i = \mathcal{S}(\vec{v}_i) \approx T1 = SKEW(V1)$$

Pseudo-Inertia Tensors

Using the notation of Reference 1 (see equation 53 or Reference 2, equation 98),

$$T_1 = S_1 [\vec{v}_1 \cdot \vec{v}_2 \ 1 - \vec{v}_1 \ \vec{v}_2]$$

$$\approx T1 = S1 * (V1 \cdot V2 * 1 - V1 V2)$$

$$= SUEOP (V2, V1, S1)$$

Subroutine SUEOP makes use of the scalar S1 and the elements stored in two arrays V1 and V2 to compute the components of the tensor T1 (see Utility Routines/SUEOP).

Normalize Vectors

$$\vec{v}_2 = \frac{\vec{v}_3 \times \vec{v}_1}{|\vec{v}_3 \times \vec{v}_1|} \approx V2 = NORM (V3 \times V1)$$

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland
December 1977

REFERENCES

- Frisch, Harold P., "A Vector Dyadic Development of the Equations of Motion for N-coupled Rigid Bodies and Point Masses," NASA Document TN D-7767, October 1974.
- Frisch, Harold P., "A Vector Dyadic Development of the Equations of Motion for N-coupled Flexible Bodies and Point Masses," NASA Document TN D-8047, August 1975.

APPENDIX A PROGRAM LISTING FOR N-BOD2

3.113

```
C
                                                                        CO100000
                                                                        CO100100
C
                                                                        C0100200
C
  C.
                                                                         C0120400
C
                                                                        CO100500
C
                             N-BCC2
C
                                                                        CO130600
    A FREGRAM TU COMPLTE THE RELATIVE ATTITUDE CYNAMICS OF
C
                                                                        CO1CO700
        N-COUPLED FLEXIBLE ECCIES, RIGIC BUDIES, POINT
                                                                        CO100800
C
            MASSES AND A SYMMETRIC WHEELS
                                                                        C0100900
C
                                                                        CO101000
c
     A CONSISTANT SET OF UNITS MUST BE USED TO DEFINE INPUT DATA
                                                                        CO101100
     THESE UNITS ARE ASSUMED CONSISTANT AND WILL BE USED IN A
C
                                                                        00101200
      CONSISTANT MANNER THROUGHOUT THE COMPUTATION
                                                                        CO101300
C
C
      NC INTERNALLY CODED CONVERSION OF UNITS IS NEEDED OF PROVIDED
                                                                        (0101400
C
                                                                         CO101500
C
     FEFEFENCES:
                                                                        C0101600
C
                        'A VECTOR-DYACIC DEVELOPEMENT OF THE EQUATIONS
       NASA TN D-7767
                                                                        CC101700
c
                         OF MOTION FUR N-COUPLED RIGIC BODIES AND
                                                                        CO1C1800
c
                         POINT MASSES!
                                                                        C0101900
C
                  BY HARCLD P. FRISCH OCT.1974
                                                                        CO102000
                                                                        CO 102100
C
      NASA IN D-8047 'A VECTCH-DYADIC DEVELOPEMENT OF THE EQUATIONS CO102200
C
c
                         OF MOTICA FUR N-COUPLED FLEXIBLE BODIES AND
                                                                        C0102300
C
                         PCINT MASSES!
                                                                        00102400
                  SY HARCLD F. FRISCH
C
                                       AUG. 1975
                                                                        CO 102500
C
                                                                        CO 102600
C
     IN FREFERATION
                      'THE N-BOD' USER'S AND PROGRAMMERS MANUEL'
                                                                        CO102700
C
                  BY HARCLD F. FRISCH SUBMITTED TO EDITORIAL 12/3/77
                                                                        C010280C
C
                                                                        CO102900
C
                                                                        C0103000
C
                                                                        C0103100
C
    N-EDC2 IS DIMENSIONED TO ACCEPT A MAXIMUM OF
                                                                        CO 103200
C
       N - BCCIES (FLEXIBLE ECDIES + RIGID BUDIES + PCINT MASSES)
                                                                        CO103300
       N - SYMMETRIC WHEELS
                                                                        C0103400
C
C
      2N - FLEXIBLE MODES OF VIBRATION (TOTAL FUR ALL FLEXIBLE BODIES) C0103500
      4N - MCCAL CRUSS-COUPLING CCEFFICIENTS (TOTAL)
C
                                                                        CO103600
C
      33 - INCEPENDENT CEGREES OF FREEDOM
                                                                        CO103700
      160 - FIRST ORDER NON-LINEAR DIFFERENTIAL EQUATIONS
C
                                                                        CO103800
C
                                                                        C0103900
C
          THIS VEHSION OF N-BCC2 LSES
                                                                         CC104000
C
                                                                        C0104100
               N = 10
C
                                                                        CO 104200
    MAKING USE UF N.L T.10 SAVES CONSIDERABLE COMPUTER STORAGE
c
                                                                        CO 104 300
C
                    N.GT.10 RUN TIME FOR PRATICAL APPLICATION EXCESSIVE CO104400
                                                                        C0104500
C
C
                                                                        CO104600
                                                                        C0104700
C
           SYMBUL LIST ABBREVIATIONS
                                                                        C0104800
C
C
     IDEM2 = N++2 + N + 1 - (N+(N-1))/2
                                                                        CO104900
c
     IDEM3 = (N-1)**2 + N - ((N-1)*(N-2))/2
                                                                        CO105000
C
      IDEM4 = SIZE OF /LOGIC/ 16 LOGICAL WORDS
                                                                        CO1C5100
C
     IDEME = SIZE OF /INTG/
                                724
                                     INTEGER WORDS
                                                                        C0105200
     IDENE = SIZE OF /INTGZ/ 70
                                      INTEGER WORDS
                                                                        CO105300
C
     IDEM7 = SIZE OF /REAL/ 4354 REAL WORDS
IDEME = SIZE OF /REALZ/ 168 REAL WORDS
                                                                        C0105400
C
      IDEME = SIZE OF /REALZ/
C
                                                                        C0105500
     IDEMS = SIZE OF /SATELL/
                               1000 REAL WURDS
                                                                        C0105600
C
     ALL COMPLIED VECTORS AND TENSURS IN COMPUTING FRAME COORDINATES
                                                                        C0105700
C
     NA = UPTION NOT AVAILABLE IN N-8JD2
                                                                        C0105800
C
                                                                        CO105900
     . = NUMBER OF
```

```
BEC = GCDY FIXED COORDINATES
C
                                                                    C0106000
     CFC = CCMPUTING FRAME FIXED COURDINATES (BODY 1 OR INERTIAL)
C
                                                                    CC106100
     IFC = INENTIALLY FIXED CCORDINATES
C
                                                                    C0106200
C
     EQIV(XMN) = EQUIVALENCED TO XMN ARRAY
                                                                    C0106300
C
     C:N = BY USE OF A CUMMY VARIABLE SUBSCRIPT O ALLJWABLE
                                                                    00106400
                                                                    (0106500
c
                    SYMBOL LIST AND STURAGE LOCATION
                                                                    C0106600
C
C
                                                                    C0106700
C
  NAME
           TYPE DIMENSION STORAGE
                                    DEFINITION AND SUBROUTINE USEC IN CO106800
C
  ----
           ----
                                    ------ C0106900
C ANGE
            F 3(N+1)
                         ECIV(XMN) EULER ANGLE COT (ANGLE. SETUP)
                                                                    C0107000
  ANDEK
                         /INTG/
                                  LUCAL WORK AREA TO SAVE STORAGE
                                                                  C0107100
             1 200
C
            F 3.N
C
  CA
                         /REAL/
                                    CM VECTUR BFC (INBS)
                                                                    CO107200
                                                                  CO107300
  CAC
                         /REAL/
                                   CM VECTUR CFC (VDIV.TRANVD)
•
C CAC
            F 3.N
                         /REAL/
                                    ZERO DEF CM VECT BFC (VCIV)
                                                                   CO107400
C CEDUM.CE
           F 3.0:N
                         /REALZ/
                                   HINGE VECTOR BFC (INBS)
                                                                   C0107500
                         /REALZ/
  CECCUM.CHC F 3.C:N
                                    HINGE VECTOR CFC (VCIV.TRANVO)
                                                                 CC1C7600
C
C
                                    HINGE VECTOR PART (INBS)
                                                                    C01C7700
            h N
                                    SCALAR TORQUE ON WHEEL (TORQUE)
. ...
                         IREAL!
                                                                    CO107800
C CNF
            R 3.N
                         ECIVIXMN) FORCE LENTRIPETAL + CORIOLIS(ETA) CO107900
C
  CCMC
            A 3.N+1
                                  ANG HATE TO COMP FRAME (RATE.CCT) CO108000
                         /REAL/
                                    COUNTER (INCPT) UNUSED AFTER
C
  CTI
             1
                         /INTG/
                                                                    C0108100
  CT2
                         /INTG/
                                    COUNTER (INCPT) UNUSED AFTER
C
             1
                                                                    00108200
C C13
                         /INTG/
                                    COUNTER (INGPT) UNUSED AFTER
                                                                    CO 108300
            1
                                    COUNTER (INCFT)+PASSES THRU (CYN) CO108400
C CT4
            1
                         /INTG/
C
  CTS
                         /INTG/
                                    CUUNTER (INUPT) UNUSED AFTER
                                                                    C0108500
             1
             6 3.N+1
C
  DCMC
                         /FEAL/
                                    PART OF ANG. ACC. VEC. (RATE)
                                                                    C0108600
            F 1000
  DLAMY
                         /SATELL/ STORAGE AREA FOR USER
c
                                                                    C0108700
 ETC
             6 J.N+1
                         /REAL/
                                    GYRC+EXT.TORG.ON NEST (ETA. GFEOT) CO108800
            F 3.N
C ETIC
                         ECIV(XMN)
                                   INERT X-COUP TURG. (ETA)
                                                                    C0108900
C
  EIM
                         /REAL/
                                    SCALAR, GENEALIZED TURQUES (QFCQT) CC109000
                         EGIV(XMN) WHEEL X-COUP TURG. (ETA)
             F 3.N
c
  FIMC
                                                                    CO 109100
C FCF
                                    MODAL CENTRIP X-COUP(INOPT.OFCCT) C0109200
            F 3.3.4N
                         /REAL/
                                    MUDAL CURIGLIS X-COUP(INOPT.QFDOT) C0109300
C FCK
            6 3.4N
                         /FEAL/
                                                                    00109400
C
  FCCN
             1 3(N+1)
                         /INTG/
                                    CODE FREE VECTORS (INBS)
C
  FGI
             L
                          /LCGIC/
                                    END OF HUN FLAG (MAIN.DYN.OUTPSP) C0109500
                                    ERROR INPUT CATA(MAIN.INERGR)
C FG2
                         /LOGIC/
                                                                   C0109600
            L
C
 FG3
                         /LCGIC/
                                   ERROR INPUT CATA(MAIN, INOPT)
                                                                    C0109700
             L
            L
                                                                    C0109800
C
  FG4
                         /LOCIC/
                                   UNUSED
                                    DUTPUT CATA ? FLAG (MAIN. TORQUE) CO109900
C
  FC5
             L
                         /LOGIC/
C FLA
            F J.2N
                                   MOCAL CM VECTUR BFC (INOPT)
                         /REAL/
                                                                    CO110000
                                    MUDAL CM VECTOR CFC (VDIV.TRANVC) CO110100
C FLAC
             4 3.2N
                         /REAL/
            F 3.2N
                         /REAL/
                                    MOCAL MOMENT VECTOR BFC (INOPT)
C FLB
                                                                    CO11 C200
C
  FLC
                         /REAL/
                                    MODAL ROTATION MCMENT BFC (INCPT) CO110300
            F 3.N
                                   GYRO FLEXIBLITY FORCE (ETA)
  FLCEC
                         /REAL/
                                                                  CO110400
C
 FLD
                         /FEAL/
                                    MODAL INERTIA DYAD BEC (INOPT)
C
            A 3.3.2N
                                                                   C0110500
                         ECIV(FLD) FLD + FLO**T (VDIV)
C FLE
            A 3.3.2N
                                                                    CO110600
C
  FLF
             R
               3.3.2N
                         EGIV(FLJ)
                                   FLD + FLH (VCIV)
                                                                    C0110700
             h 3.N
  FLIFC
C
                         /REAL/
                                    GYRO FLEXIBLITY TORQUE (ETA)
                                                                   C0110800
C FLJ
             F J.3.2N
                         /REAL/
                                    MUDAL RETATION DYAD BEC (INOPT) CO110900
C FLQ
             F 3.2N
                         EGIV(FLE) MUDAL MCMENTUM VECTUR BFC (VCIV) CO111000
            F 3.2N
                                    FLU IN CFC (VDIV.TRANVD)
  FLGC
                         /REAL/
                                                                    CO111100
C
  FLCM
                         /REAL/
                                    MUCAL FREQUENCY (INOPT)
                                                                    C0111200
C
C FCMC
            6 3.N+1
                         /REAL/
                                    INERTIAL RATE VECTOR (RATE)
                                                                    C0111300
                                   HINGE TO CM VECTOR (VDIV. XDY)
C GAN
            F 3.IDEM2
                         /REAL/
                                                                   CO111400
            E
                                    INTEGRATION STEP SIZE (FUNGE. INES) CO 11 1500
CH
                         /REAL/
            F 3.N
C
  HN
                         /REAL/
                                    WHEEL SPIN AXIS HEC (INBS)
                                                                    CO111600
                                   WHEEL SPIN AXIS CFC (VDIV.TRANVD) CO111700
  HMC
C
                         /REAL/
             F N
                                   WHEEL ANGULAR MOMENTUM (INBS. SETUP) CO111800
 FMCH
                         /HEAL/
                                    SIZE OF /LUGIC/ (RSTART)
C ICENA
                         LOCAL
                                                                    CO111900
```

```
ICEP5
                           LOCAL
                                      SIZE OF /INTG/ (RSTART)
                                                                         00112000
                                      SIZE OF /INTGZ/ (RSTART)
  ICEN6
                           LCCAL
                                                                         C0112100
C
              1
                                       SIZE OF /REAL/ (RSTART)
c
   ICEM7
                           LCCAL
                                                                          CC1122CO
                                      SIZE OF /REALZ/ (RSTART)
C
   ICEMB
              1
                           LUCAL
                                                                         C0112300
                                       SIZE OF /SATELL/(RSTART)
C
   ICE#9
              1
                           LOCAL
                                                                          C0112400
C
   IIAII
              1
                 I DEMS
                           EGIV(ABORK) ZEHO OUT /INTG/ (ASTART)
                                                                         CO112500
C
   INERF
              L
                           /LOGIC/
                                      FLAG, BFC OR IFC FOR CFC (INOPT)
                                                                          CO 11 2600
C
   IZINIT
              1
                 I DEM6
                           EGIV(SCNDUM)ZERO OUT /INTGZ/ (RSTART)
                                                                          CO112700
C
   JCCA
                           /INTG/
                                      BUDY CONNECTION MATRIX (INBS)
                                                                          00851100
              1
                 N
                 2(N+1)
C
   LCON
              1
                           /INTG/
                                       CUDE . LUCKED VECTORS (INES)
                                                                          CO112900
C
   LANGLE
                           /LCEBUG/
                                      PRINT EQUATIONS IN ANGLE? (MAIN)
                                                                         CO113000
              L
C
   LCCT
              L
                           /LDEBUG/
                                      PRINT EGUATIONS IN DCT? (MAIN)
                                                                          CO113100
c
  LEGL
                           EGIV( )
                                      EQIV IN EACH SUB TO PRINT FLAG
                                                                          C0113200
              L
   LEGUIV
C
                           /LDEEUG/
                                       PRINT EGUATIONS IN EGIV? (MAIN)
                                                                          C0113300
                                      PRINT EQUATIONS IN ETA? (MAIN)
                                                                         CO113400
C
   LETA
                           /LDEBLG/
   LINIT
                 I DEMA
                                       ZEHO OUT /LOGIC/ (RSTART)
                                                                          00113500
C
              L
                           EGIV(FGI)
                                      PRINT EQUATIONS IN OFDOT? (MAIN) CO113600
                           /LDEEUG/
C
   LOFCCI
              L
c
  LEATE
                           /LDEBUG/
                                       PRINT EGUATIONS IN RATE? (MAIN)
                                                                          C0113700
              L
  LRTAPE
                                      CREATE RESTART TAPE? (MAIN)
                                                                          CC113800
C
              L
                           /CHEKS/
C
  LAUNGE
              L
                           /LCEBUG/
                                      PRINT EQUATIONS IN RUNGE? (MAIN)
                                                                         CO113900
C
   LSETUF
                           /LDEBUG/
                                      PRINT EQUATIONS IN SETUP? (MAIN)
                                                                         CC114000
C
  LSIMO
                           /LDEBUG/
                                      PRINT EQUATIONS IN SIMO? (MAIN)
                                                                         CO114100
              L
                                      PRINT EQUATIONS IN TORQUE? (MAIN) CO114200
  LTCFQL
C
                           /LDEBUG/
C
   LTEAN
                                      PRINT EQUATIONS IN THAN? (MAIN)
                                                                         CO114300
              L
                           /LDEBUG/
                                      PRINT EQUATIONS IN TRANVO? (MAIN) CO114400
C
   LTRANV
              L
                           /LDEBUG/
                                      PRINT EQUATIONS IN TRNSIV? (MAIL) CO114500
C
   LIENSI
              L
                           /LDEBUG/
                                       PRINT EQUATIONS IN VDIV? (MAIN)
C
  LVDIV
                           /LDEBUG/
                                                                         C0114600
              L
c
                                      PRINT EQUATIONS IN XDY? (MAIN)
                                                                         CO114700
   LXDY
              L
                           /LDEBUG/
C
   MC
              I
                           /INTE/
                                       BUDY IN WHICH WHEEL IS IN (INES)
                                                                         CO114800
                 N
                                       NUMBER OF BCDIES (INBS)
C
   NECC
              1
                           / INTG/
                                                                         CO114900
C
   NEL
              1
                           / ENTG/
                                       NUMBER OF BCDIES + 1 (INBS)
                                                                         C0115000
                                       (INCPT.NA) CONSTRAINT TORQUES
C
   NCTC
              1
                           /INTG/
                                                                         CO115100
C
   NEQ
              1
                           LOCAL
                                       # EQUATIONS SETUP BY N-BOC2 (EGIV) CO115200
C
   NFER
              1
                           /INIG/
                                       # FREE COURD VECTORS (INBS)
                                                                         CO115300
   NFKC
                           /INTG/
                                       (INOPT.NA) CENSTRAINT FORCES
                                                                         CO115400
C
              1
C
   NFL XB
                           /INTG/
                                       # FLEXICLE BODIES (INJPT)
                                                                         CO115500
   NERC
                           /INTG/
                                       # RELATIVE ANGLES CEMPUTED (INOPT) CO 115600
C
              1
C
   NLOR
                           /INTG/
                                       . LOCKED COCRD VECTORS(INBS)
                                                                         C0115700
                                       TOTAL NUMBER OF WHEELS (INBS)
C
   NNC
                           /INTG/
                                                                         CC115800
              1
C
   NMOA
                           /INTG/
                                       # WHEELS TO COMP REL ANGLE (INOPT) 00115900
              1
                                       TOTAL # NUDES FOR SYSTEM (INOPT) CO116000
C
   NECS
              1
                           /INTG/
C
   NAV
              I
                           /INTG/
                                       * VARIABLE SPEED BHEELS (INOPT)
                                                                         C0116100
   NSTART
                                      NEW CR RESTART RUN? (MAIN)
C
              L
                           /CHEKS/
                                                                         C0116200
                                       # LOCKED VECTORS TRANSFURM(VCIV) CO116300
C
   NEVP
                           /INTG/
              1
   NSYC
                                       # FREE VECTORS TRANSFORM (VCIV)
C
              1
                           /INTG/
                                                                         C0116400
                                      # DIFF EQS.IN SUB TORQUE (TORQUE) CO116500
C
   NTO
                           /INTG/
              1
C
   PCGA
              1
                 N+1
                           /INTG/
                                      # CCNSTRAINED AXES AT HINGES(INES)CO116600
C
   PHI
              R
                3.N+1
                           /REAL/
                                      EXTERNAL TORQUE CN NEST (TORQUE) CO116700
                 N
C
   PLM
              6
                           /REAL/
                                       WHEEL SPIN INERTIA (INBS)
                                                                         C0116800
C
   CF
              R
                 3.3(N+1)
                           /REAL/
                                      FREE VECTOR BFC (INBS)
                                                                         00116900
                                      FREE VECTOR CFC (VDIV.TRANVD)
C
   CFC
              F
                 3.3(N+1)
                           /FEAL/
                                                                         CO117000
                                      LOCKED VECTOR OFC (INBS)
                                                                         CO117100
C
   GL
              .
                 3.2(N+1)
                           /REAL/
C
   OLC
                 3.2(N+1)
                           /REAL/
                                      LOCKED VECTOR CFC (VDIV.TRANVE)
                                                                         C0117200
C
   RPLC
              1
                           /LOGIC/
                                      RIGIC BODY OR POINT MASS? (INBS) CO117300
                 N
   RINIT
                 I DEM7
                           EGIVICAL
                                      ZERO OUT /REAL/ (RSTART)
                                                                         CO117400
C
              F
C
   FCPC
              F
                 3.N+1
                           /REAL/
                                      RELATIVE FATE VECTOR (RATE)
                                                                         CO117500
   RZINIT
                 LDENH
                           EQIV(CEDUM) ZERC OUT /REALZ/ (HSTART)
                                                                         CO117600
C
  SC
              1
                 3(N+1)
                           /INTG/
                                      FREE VECTORS CAGED (INOPT.UNCAGE) CO117700
C
   SCC
                           /INTG/
                                      UNLSED
                                                                         CO117800
              1
                 N
  SCG
              1
                           /INIG/
                                      # CAGED DEGREES (INOPT.UNCAGE)
                                                                         CO117900
```

```
SCNEUM.SCN I D:N-1
                           /INTGZ/
                                        CODE, CENTRIPETAL EFFECTS (INOFT) CO118000
   SCHOUP. SCR I
                            /INTGZ/
C
                  0:N-1
                                        CODE.CURIOLIS EFFECTS (INOPT)
                                                                           C0118100
                            ECIVITORQ) CODE.X-COUP MODES (INOPT. OFCOT)
C
   SCXC
               1
                  2 N
                                                                           C0118200
                            /INTG/
C
   SD
                                        CUDE DIRECTION COSINES (INOPT)
                                                                           C0118300
C
                            /INTG/
   SEU
                                        CODE.EULER ANGLES (INOPT)
                                                                           C0118400
C
   SECC
                            /INTG/
                                        CODE. HUDIES FLEX X-COUPLING (INOPTCO118500
C
   SFKDUM. SFK I
                  0:N-1
                            /INTGZ/
                                        CODE.CONSTRAINT FORCE(INOPT.NA)
                                                                           C0118600
C
   SFLX
               1
                            /INTG/
                                        CODE.ALL FLEXIBLE BODIES (INOFT)
                                                                           CO116700
C
              1
                  3(N+1)
                            /INTG/
                                        CODE, CUMPUTE FREE VEC ANGLE (INOPT) 00118800
C
   CERN
              1
                 N
                            /INTG/
                                        # MODES EACH BODY (INCPT)
                                                                           CC118900
C
   56
                            /IN1G/
                                        CODE, ALL GYACSTATS (SETS)
               1
                                                                           C0119000
C
   SI
               1
                  I DEMS
                            /INTG/
                                        CADE. BUDIES HINGE TO CM (SETS)
                                                                           C0119100
C
                            /INTG/
   SIG
                                        UNUSED
                                                                           C0119200
C
   SIXCUM.SIX I 0:11-1
                            /INTGZ/
                                        CODE.INERTIA EFFECTS (INOPT)
                                                                           C2119300
C
   SKOLM . SK
              1
                 0:N-1
                            /INTGZ/
                                        CODE. BODIES IN EACH NEST (SETS)
                                                                           C0119400
C
   SL
               1
                            /INTG/
                                        CODE.ALL POINT MASSES (SETS)
                                                                           CO119500
C
   SLK
                  3(N+1)
                            /INTG/
                                       CODE.CONSTRAINT TORQUE(INOPT.NA)
              1
                                                                          CC119600
C
   SWA
                            /INTG/
                                        CODE . WHEEL ANGLE COMPUTE (INOPT)
              1
                                                                           C0119700
c
   SWAL
                            /INTG/
                                        CODE . SMALL ANGLES (INOPT)
               1
                                                                          C0119800
C
   SMCCUM. SMC I
                  0:N-1
                            /INTGZ/
                                        CODE.ALL WHEELS IN NEST (INOPT)
                                                                           00119900
C
  SHV
                            /INTG/
                                       CODE. VARIABLE SPEED WHEELS (INOPT) C0120C00
               1
C
   SCK
                 N+1
                            /INTG/
                                        CODE. BODIES HINGE 0 - CM (VDIV)
                                                                          C0120100
C
   SPICUM.SPI I
                 0:1-1
                            /INTGZ/
                                       CUDE . PSUEDO INERTIA TENSORS (INOPT) CO 120200
C
   SCF
                  N+1
                            /INTE/
                                        CODE. FREE VECTUR AT HINGE (SETS)
                                                                          (0120300
C
   SCL
               1
                 N+1
                            /INTG/
                                       CODE.LOCKED VECTOR AT HINGE (SETS) CO120400
C
                            /INTG/
                                       CCDE.ALL RIGIC BODIES (SETS)
                                                                         C0120500
C
  SECA
              1
                            /INTG/
                                       CODE, UNION CF ALL SCN (VDIV)
                                                                          C0120600
C
   SSIX
               ı
                            /INTG/
                                       CUDE . UNION CF ALL SIX (VOIV)
                                                                          00120700
  SVA
C
               1
                            /INTG/
                                       CODE.CM VECTORS TRANSFORM (VCIV) CO12080C
C
  SVE
                            /INTG/
                                       CODE.HINGE VECTORS TRANSFORM(VCIV) CO12090C
               1
C
  SVD
               1
                            /INTG/
                                       CUDE.DCN'T THANSFURM (INOPT)
                                       CODE. INERTIA DYAD TRANSFORM (VDIV) 00121100
C
   SVI
                            /INTG/
              1
c
  SVM
               1
                            /INTG/
                                       CODE.SPIN VECTORS TRANSFORM(VCIV) CO121200
C
  SVP
              I 2(N+1)
                            /INTG/
                                       CUDE . LJCKED VECTORS TRANSFORM(VCIVCO121300
C
   SVQ
              1 3(N+1)
                            /INTG/
                                       CODE. FREE VECTORS THANFCRM(VCIV) CO121400
C
   SXM
              ı
                 3 . N
                            /INTG/
                                       CODE. SMALL ANGLE KINEMATICS (INDPT) CO 121500
C
   S x T
              1
                            /INTG/
                                       CUCE, TIME VARY CUL INER MAT(INOPT) 00121600
C
                            /REA_/
                                       TIME (MAIN)
                                                                           C0121700
  TEM
              F 2.160
                            LCCAL
                                                                           00812100
C
                                       TEMP STORAGE AREA (RUNGE)
              F
C
  THA
                 43
                            /HEAL/
                                       GENEALIZED COORDINATES (INBS. SETUP) CO 12 1900
   THAC
              F
                                       GENERALIZE COORD RATE (INES.SETUP) CO122000
C
                 33
                            /REAL/
                                       GENERALIZE COURD ACC (SETUP.SIMO) CO122100
  THACD
C
              H
                 33
                           EGIV(ETM)
C
  THACH
              F N
                            /REAL/
                                       .HEEL RATE (INBS. SETUP)
                                                                          C0122200
c
  THAN
              6 14
                            /REAL/
                                       WHEEL ANGLE (INBS. SETUP)
                                                                          C0122300
C
   TIMEND
              4
                            /REAL/
                                       TIME TO END RUN (INBS.DYN)
                                                                          C0122400
C
   TCRG
              1
                 47
                           /INTG/
                                       UNUSED STURAGE AREA FOR USER
                                                                          C0122500
C
  TLG
                3(N+1)
                           /FEAL/
                                       TIME TO UNCAGE (INDPT.UNCAGE)
                                                                          CO122600
              A 3.3. IUEN2 /FEAL/
                                       MATRIX OF INERTIA TENSORS(VCIV. XCYCO122700
C
   XCIC
                                                                          C0122800
C
   XI
              P
                 3.3.N
                           /REAL/
                                       INERTIA DYAC BFC (INBS)
                                       INERTIA DYAC CFC (VDIV, TRANVE)
C
   XIC
              -
                 J.3.N
                            /REAL/
                                                                          (0122900
                                       ZERU INERTIA DYAD BFC (VCIV)
C
   XIG
                 3.3.N
                           /REAL/
                                                                          C0123000
              F
C
   XMAS
                            /REAL/
                                       BUDY MASS (INBS)
                 24
                                                                          C012310C
   XMCCUM.XMC &
                 3.3.C:N
                           /REALZ/
                                       TRANSFURM BFC TO CFC (TRNSIV.TRAN)00123200
C
                           IREAL!
C
   XMN
              E
                 33.33
                                       SCALAR INERTIA MATRIX (VDIV. OFDCT) C0123300
C
                 160
                           LOCAL
                                       SYSTEM STATE (EGIV. SETUP. TORQUE) CO123400
C
   YC
                                       SYSTEM STATE DERIV (SETUP, TORQUE) CO123500
                 1 =0
                           LOCAL
¢
   YMCC
              F
                 J.2.N+1
                           ECIV(XMN)
                                       DIRECTION COSINE HATES (DCT)
                                                                          C0123600
C
   LUT
                 3.3.N
                           /HEAL/
                                       ZERO STATE TRANSFORMTION MAT(INES) 00123700
  ZETA
             R 2N
                           /FE AL/
                                      MOCAL DAMPING RATIO (INUPT)
                                                                         C0123800
C
                                                                          00023900
```

C			,	0124000
č			-	0124100
č	SI SE WITTE	LCCATICN		0124200
č	3CEROOT INC	LUCATION	-	0124300

c	MIN	00000100		0124400
C	CYN	0020000		0124500
c	FSTART	0030000		0124600
C	1865	00400000		0124700
C	INERCH	0050000		0124800
C	SETS	0000000		0124900
c	INJFT	00700000	C	0125000
C	INTCH	0030030	c	0125100
C	THNSIV	00900000	· · · · · · · · · · · · · · · · · · ·	0125200
•	VOIV	0100000	C	0125300
c	VIDE	01100000	c	0125400
c	TRAN	0120000	c	0125500
c	TRAND	01300000	7	0125600
c	FATE	01400000		0125700
č	ACY	01500000	7	0125800
č	ETA	C16CCC00		0125900
č	TCROLE	C17C0C00		0126000
č	CFOCT	01800000		0126100
c	CCT	01900000		0126200
c	ANGLE	02000000		0126300
C	SETUP	0510000		0126400
C	CUTPLT	622 00 000		0126500
C	CLTPSP	02300000		0126600
C	SIMG	0240000	c	0126700
C	FUNGE	02500000		0159800
c	LNCAGE	0260000	c	0126900
c	CCMFFS	02602600	c	0127000
C	LNPHS	02605190	c	0127100
C	CCMFAC	0506660	c	0127200
C	LNPAC	02669100	c	0127300
C	K10	02612200		0127400
C	KT1	02613000	c	0127500
C	CTAIN	02613600		0127600
C	VECTEN	02700000		0127700
	TENTAN	02702000		0127800
c	VECNEM	C2704600		0127900
c	PATPUL	02706100		0128000
c	TENSES	02707400		0128100
č	104	0276860		0128200
c	VECACO	02800000		0128300
c	VECSLU	02801000		0128400
c	SCL V	02861500		0128500
C	VECCCT	02802600		0128600
c	VECACS	02863600		0128700
C	TRIPVP	02864400		0128800
C	CYADE	0396600		0128900
C	SCLC	02807000		0129030
C	CYDCTV	05966600	C	0129100
C	VXUYCV	02868660	C	0129200
C	CYTCV	02911000	C	0129300
C	VEDYEV	02812400	C	0129400
C	CYOP	02813500	C	0129500
C	SLECP	02815400	C	0129600
c	CLTMU	C29C0C00	c	0125700
C	CLATCP	02902200	c	0129800
C	THANSU	02903300		0129900

```
C0130000
C
C
                                                                       C0130100
      IMPLICIT HEAL+ 8(A-+ . 0-2.1)
                                                                       C0130200
     LOGICAL FG1. FG2. FG3. FG4. FG5. INERF. RBLO. LEGU. LINIT(1)
                                                                      C0130300
                     NETART. LRTAPE
     LOGICAL
                                                                       C013040C
     LOGICAL
                     LALNGE . LIANSI . LVDIV . LEGUIV . LTRAN .
                                                                      C0130500
                     LTRANV . LRATE . LXDY . LETA . LTGEGU .
                                                                       C0130600
                     LCFDOT . LCCT . LANGLE . LSETUP . LSIMO
                                                                      (0130700
C
                                                                       (0130800
C
                                                                       (0130900
     INTECEN
                                                                       C0131000
                    . CT2 . CT3 . CT4 . CT5 . FCON . PCON .
     . ABCRK . CTI
                                                                      CO 131100
                                                          • SG
                                                                  •
                                                   . SFR
     . SCNCUM. SCN
                   . SCRDUM. SCR
                                    . SFKDUM . SFK
                                                                      C013120C
                    . SIXDUM. SIX
                                   . SKDUM . SK
                                                           . SLK
     . 51
           . 516
                                                   . SL
                                                                      CO 131 300
                                           . SPIDUM. SPI
                                                          . SOF
     . SHA
            . SMCDUM. SMC . SMV
                                    . SUK
                                                                      CC131400
                                                          . SVI
                                                                  . 00131500
     · SCL
            . SR
                  . SSCh . SSIX . SVA
                                           . SVE . SVD
                                   SXT . TURQ . SMAL . SEU
                   . SVQ . SXM
. NFLXB . SFLX
            . SVP
     . SVM
                                                                      CO131600
     * SC
            . SCG
                                                                      CO131700
     · IINIT(1)
                   · IZINIT(1)
                                   . 50
                                           . SCXC(20)
                                                                      C013180C
C
                                                                       C0131900
C
                                                                      CC132000
     REAL .
                                                                      C0132100
                    . CAF (3.10) . ETIC (3.10) . ETMC (3.10) . C0132200
     . ANGC (33)
     • FLO (3.20) . FLE (3.3.20). FLH (3.3.20).
                                                                       CO132300
     * THACO (33)
                 . YMCD (3,2,11), RINIT (1)
                                                  . HZINIT(1)
                                                                       CO132400
C
                                                                       CO132500
C
                                                                      C0132600
     COMMON /CHEKS/
                              NSTART, LRTAPE
                                                                      C0132700
C
                                                                      00132800
     CCMMCN /LUEBUG/ LFUNGE . LTRNSI . LVDIV . LEGUIV . LTRAN .
                                                                      00132400
                    LTRANY . LRATE , LXDY , LETA , LTORGU , LGFDGT , LDCT , LANGLE , LSETUP , LSIMG
                                                                      CC133000
                                                                      C0133100
C
                                                                      C0133200
     COMMON /LUGIC/ FG1. FG2. FG3. FG4. FG5. INERF. HELD(10)
                                                                      CC133300
C
                                                                      C0133400
                                                                      C0133500
C
                     ANORK (200)
     COMMEN /INTO/
                                                                      CC13360C
     . 511
                    . (12
                                    · CT3
                                                  . CT4
                                                                     C0133700
                                   . JCON (10)
     · C15
                    . FCON (33)
                                                  . LCUN
                                                          (22)
                                                                      C0133800
     . MC
            (10)
                   . NB1
                                    . Ná00
                                                    . NCTC
                                                                      C013390C
                                   . NERC
                    . NEKC
                                                   . NLOR
     . NEER
                                                                      C0134000
                    . MMG
                                    . NMOA
     . ...
                                                   . NSVP
                                                                     00134100
                    . FCON (11)
                                    . 50
                                                    . SFR
                                                          (33)
                                                                   . 00134200
     . NSVC
     • SG
                    . 51
                            (55)
                                   . 516
                                                   . SL
                                                                      CO134300
                    . SMA
                                                   . SQF
                                          (11)
                                                           (11)
                                                                      CO134400
     . SLK
            (23)
                            (10)
                                    . SOR
                                    . SR
                                                    . SSCN
                    . SMV
                                                                      C0134500
     · SGL
            (11)
                    . SVA
                                    . SVH
                                                    . SVD
                                                                      CO134600
     . SSI>
                                    . SVP
                                                   . SVU
                    . SVM
                                           (22)
                                                           (33)
                                                                      CC134700
     · SVI
                                                   . SMAL
                                    . TURO (97)
     · SXM
                   . SXT
                                                                      C0134800
            (3.10)
                    . ATQ
                                    . SC
     . SEU
                                           (33)
                                                   . SCG
                                                                   . C013490C
                   . SFLX
                                    . SF XM (10)
                                                   . NHODS
                                                                   . 00135000
     · NFL 25
                    . SCC (10)
                                                                      C0135100
     · SFCC
                                                                      CO 13520C
C
                                                                      CO 135300
C
     CCMMCN /INTGZ/
                                                                   . CO 13540C
                                                                   . 00135500
                                                  . SCR
     . SCNCUM
               . SCN
                            (6)
                                  . SCRDUM
                                                           (9)
                   . SFK
                                   . SIXDUM
                                                  · SIX
                            (5)
                                                           (9)
                                                                      C0135600
     . SFKCLM
                                                                   . 00135700
                   . SK
                                    . SPIDUM
     . SKOLA
                            (6)
                                                           (9)
     . SMCCUM
                   . SMC
                            (5)
                                                                      C013580C
                                                                      C0135900
C
```

```
C
                                                                            C0136000
                                                                            CC136100
     CCHMCA /REAL/
     . CA
             (3.10)
                     . CAC
                             (3.10) . CLM
                                              (10)
                                                      . CCMC (3.11)
                                                                           C0136200
             (3.11) . ETC
(3.60) . F
                                                       . FCMC
    . DCMC
                             (3.11)
                                      . ETM
                                              (33)
                                                               (3.11)
                                                                           CC136300
    . GAM
                                      . HM
                                              (3.10)
                                                      . HMC
                                                               (3.10)
                                                                           C0136400
                                      . PLM
                                                       . OF
     . HACH
            (10)
                     . F+1
                              (2.11)
                                               (10)
                                                               (3.33)
                                                                           C0136500
                                                      , RUMC
     · QFC
                                                               (2.11) .
             (3.35) . OL
                              (3.22)
                                      · arc
                                              (3,22)
                                                                           C01366C0
                                                       . THAD
                                                                            C0136700
                                                               (33)
                                        THA
                                               (33)
                      . THAM (10)
                                                               (3.3.10).
                                                                           C0136800
    . THACA (10)
                                      . XDIC
                                              (3.3.00). XI
     · XIC
            (3.3.10). XMAS (10)
                                      . XMN
                                              (33.33) . XMT
                                                               (3.3.10).
                                                                            C0136900
                                                               (3.20)
     . TLG
             (33)
                    . FLA
                             (3,2C) . FLB
                                              (3.20) . FLC
                                                                           C0137000
     . FLD
             (3.3.20). FLJ
                             (3.3.20), CAD
                                             (3.10) . X10
(3.20) . FLOC
                                                               (3.3.10).
                                                                            C0137100
     • FLIRC (2.10) . FLCRC (3.10) . FLAC
                                                              (3.20) .
                                                                            C0137200
     • FLC + (20)
                     . ZETA (20)
                                      . FCF
                                              (3.3.40). FCK
                                                               (3.40)
                                                                           00137300
     . TIMEND
                                                                            C0137400
C
                                                                            CC137500
                                                                            C0137600
C
     CCAMEN /FEAL Z/
                                                                            C0137700
     . CADLM (1.3)
                              (3.10) . CaCDUM(1.3)
                                                       · CBC
                                                               (3.10)
                                                                           C0137800
                     . CE
                             (3.3.10). CHN(3)
                                                                            C0137900
     . XMCCLM(1.1.5) . XMC
C
                                                                           C0138000
                                                                           C0138100
C
C
     /SATELL/ AREA RESERVED FLR USER REQUIRED CATA
                                                                            C0138200
                                                                            CO 138300
C
     CONNEN /SATELL/ DIMMY(1000)
                                                                            C0138400
C
                                                                           C0138500
     EQUINALENCE (ETM(1). THADE(1))
                                             .(XMN(1.1).ANGD(1))
                                                                           C0138600
                  (XMN(1.3).YMCC(1.1.1))
                                             . (XMN(1.6).CNF(1.1))
                                                                           (C13870C
                  (XMN(1.8).ETIC(1.1))
                                             . (XMN(1.10).ETMC(1.1))
                                                                           C0138800
                                             .(FLE(1.1.1).FLD(1.1.1)).
                  (FLG(1.1).FLG(1.1))
                                                                           C0138900
                                                                           C013900C
     .
                  (FLH(1.1.1).FLJ(1.1.1))
                                             .(CA(1.1).HINIT(1))
                                                                           C0139100
                  (FGI.LINIT(1))
                                             . (A.ORK(1). (INIT(1))
                                                                           CC139200
                  (CUDUM(1.1). FZINIT(1))
                  (SCNOUP.IZINIT(1))
                                             . (TORG(78).SCXC(1))
                                                                           C0139300
                                                                           CO139400
C
                                                                           C0139500
C
                                                                           00139600
C
                                                                           C0139700
     CINE & SICK V(160) . YC(160) . TEN(2.160)
                                                                           C0139800
C
                                                                           C0139900
C
     HETURN HERE FOR START OF NEXT RUN
                                                                           CC140000
C
    1 CONTINUE
                                                                           C0140100
C
                                                                           CO 140200
                                                                           CO140300
C
      INPUT CENTRUL CARD
     SE 10 (5.102.END=7)
                                                                           C014040C
                No TART . LHUNGE . LTH ASI . LVDIV . LLQUIV . LTRAN . LTRANV . LRATE .
                                                                           C0140500
     .
                       LXDY.LETA,LTJRQU.LQFDUT.LDCT.LANGLE.LSETUP.LSIPQ.C0140600
                       LATAPE
                                                                           CO 140700
                                                                           C0140800
     LOGIC CENTHUL PARENETERS FOR N-0002
                                                                           C0140905
      NETART = .THUE. A RESTART RUN AT T.NE.O
0
                                                                           C0141000
      NETART = .FALSE. STANCARD FUN START AT T.EG.O
                                                                           C01411C0
C
      LEGE - THUE. PRINT ECUATIONS
                                                                           00514100
C
                        BYPASS PHINTING
                                                                           CO141300
      LEGL = .FALSE .
C
      LATAPL = .TRUE.
                        CON'T CREATE A HESTART TAPE
                                                                           CO141400
C
      LATAPE = .FALSE. CHEATE A RESTART TAPE
                                                                           C0141500
C
                                                                           C0141600
     ZERO ALL COMMON BLOCKS OF FILL THEM IN FROM THE RESTART TAPE
                                                                           CO 14 1 700
C
     CALL ROTART (1.Y.YC.NEG. TEN. 62)
                                                                           C0141800
                                                                           CC141900
```

```
00142000
C
      INFUT DESCRIPTION OF BASIC SYSTEM
             TEPOLOGY
                                                                             CO142100
C
             INERTIA
                                                                             C0142200
C
             MCHENTUM AFEELS
C
                                                                             CO 142 300
             GEOME THY
                                                                             CO142400
C
C
             ACMINAL STATE
                                                                            C0142500
             KINEMATICAL CONSTRAINTS
C
                                                                            CO 142600
C
             INPUT INITIAL CONDITIONS
                                                                            CC142700
C
                     RATES
                                                                            C0142800
C
                     DISPLACEMENT
                                                                            C0142900
                     FREE COORC INATES
                                                                            CC 143000
C
C
                     MOMENTUM MEELS
                                                                            CO 14 31 00
                     INTEGRATION TIME STEP
0
                                                                            C0143200
      CALL INES
                                                                            C0143300
     CHECK FOR PHYSICALLY REALIZABLE SYSTEM
C
                                                                            CO143400
      CALL INLAUN
                                                                            C01435C0
      IF ( . NCT . FUZ) GC TC 4
                                                                            C0143600
      FG2 FESET FALSE IN INERUF IF PHYSICALLY UNHEALIZABLE
C
                                                                            CO 143700
C
                                                                            CO143HOO
C
     COMPLTE EUDY LABEL SETS NEEDED FUR SUMMATION CHAINS
                                                                            C014390C
     CALL SETS
                                                                            CC144000
C
                                                                            CO 14410C
C
     INPUT COMPUTATION OFFICES
                                                                            CO 144200
             FRAME OF COMPUTATION
                                                                            CO144300
C
C
             ALGMENTED SETS FOR SUMMATION TRUNCATION
                                                                            CO144400
             CINECTICN COSINE DELETION
0
                                                                            C0144500
C
             CLLUMNS OF INERTIA TENSUR DELETION
                                                                            C0144600
             TRANSFURMATION SUPPRESSION
                                                                            C0144700
C
C
             ELLER ANGLE TECHNIQUES
                                                                            CO 144800
             SMALL ANGLE ASSUMPTIONS
C
                                                                            C0144900
C
             ANGULAN DISFLACEMENT
                                                                            C0145000
             MCMENTUM SPEEL PATE
                                                                            CO 145100
C
C
             MEMENTUM AFEEL ANGLE
                                                                            CO145200
C
             FLEXIBLE BCCIES
                                                                            CO145300
C
             WEUAL COUPLING
                                                                            C0145400
C
             CAGED DEGREES OF FREEDJA
                                                                            CO145500
     CALL INCET
                                                                            CO 145600
     IF ( . NCT . FUJ) GC TO 4
                                                                            CO 145700
     FG3 FLSET FALSE IN INDPT IF COTION CARD NUT RECUGNIZED
C
                                                                            C0145800
C
                                                                            C0145900
     INFLI PARAMETERS NEEDED TO DEFINE EXTERNAL DISTURBANCES
                                                                            CO146000
C
C
             GRAVITY
                                                                            00146100
             GHAVITY GRACIENT
C
                                                                            CC 146200
C
             CHELT
                                                                            CO 146 30C
             LCCALLY APPLIED FCRCES
                                                                            C0146400
C
             SFRINGS
                                                                            C0146500
C
             CAMPERS
                                                                            C0146600
C
             MCTUHS
                                                                            C0146700
                                                                            C0146800
             PLMENTUM BEEL CONTROL
C
             CENTRUL SYSTEMS
                                                                            CO 146900
C
             THERMAL DEFCEMATION
                                                                            CO14 7000
C
                                                                            CO147100
C
             LTHEH
     CALL INTER
                                                                            CO14720C
C
                                                                            00147300
t
     CCMPLTE INTITIAL VALUES FOR ALL SYSTEM PAREMETERS
                                                                            CQ 14740C
(
             TRANSFORMATION MATHICES
                                                                            C0147500
             CENTER OF MASS VECTORS
                                                                            CO147600
C
            PINGE POINT VECTORS
                                                                            CO147700
C
                                                                            CO147800
C
            INCRTIA TENSON
                                                                            CO14790C
C
            FREE VECTURS
```

```
LCLKED VECTORS
                                                                            C0148000
C
             HATE VECTORS
                                                                            C0148100
C
             COMPUSITE VECTORS AND DYADE
                                                                            C0146200
C
             CRUSS COUPLING
                                                                            C0148300
             EXTERNAL DISTUREANCES
C
                                                                            CO 148400
C
             SYSTEM DYNAMICS
                                                                            C3148500
C
             MEMENTUM OFFEEL DYNAMICS
                                                                            C014860G
C
             ACCELERATION ABOUT-ALONG FREE VECTORS
                                                                            C0148700
             CINECTION COSINE FATES
C
                                                                            C0148800
      T = C
                                                                            00146900
     CALL DYN(Y.YD.NEG)
                                                                            C0149000
      CUTPLT TCTAL SYSTEM STATE AT T=0
                                                                            C0149100
      CALL OUTPUT
                                                                            CC149200
      FRINT 101
                                                                            CC149300
      LALL DUTFSP
                                                                            C0145400
C
                                                                            C0149500
                                                                            00149600
C
     START CASIC INEGRATION OF SYSTEM EQUATIONS OF MOTION
                                                                           C0149700
C
        LSE FIXED STEP FLURTH CADER HUNGE KUTTA
                                                                            C01498C0
   2 CCATINUE
                                                                           C0149900
C
      CECRESS OF FREEDOM MAY BE UNCAGED CHLY AT THE START OF
                                                                           C0150000
       AN INTEGRATION STEP. CHECK IN UNCAGE IF IT IS TIME TO
C
                                                                            C0150100
C
       UNCACE. SCG.EG.O IMPLIES NO MURE UNCAGING TO BE DONE
                                                                           C0150200
C
       NCTE: INITIAL UNCAGING VELCCITY = 0. IMPULSE EFFECTS
                                                                            C0150300
              HAVE NOT EEEN CODED IN PROGRAM
C
                                                                            C0150400
      IF (SCG.EG.O) GG TC 3
                                                                            C0150500
                                                                            C0150600
     CALL LNCAGE( SCG. SC. T. TLG)
    3 CCATINUL
                                                                            CC15370C
      CALL HUNGE(T. P. Y. YE . NEG . NTG . TEM)
                                                                            C0150800
C
                                                                            10150900
     SUBHOUTINE HUNGE CALLS DYN IN WHICH ALL SYSTEM DIFFERENTIAL
                                                                            CC15100C
C
        EGUATIONS ARE SETUP AND PUT IN THE YO ARRAY
C
                                                                            C0151100
C
                                                                            C0151200
C
     CHECK END UF HUN FLAG
                                                                            C0151300
     IF (.ACT.FGI) GU TC 5
                                                                            CO151400
     CUTPLT COMPUTED PARAMETERS
                                                                            C0151500
C
     IF FCE THUE PRINT
                                                                            C0151600
      IF FCS FALSE SKIP PRINT AND CU TU RUNGE
                                                                           CO 151 700
C
      CEFALLT FUR FGS IS TRUE BUT MAY BE EVERRIDDEN IN TURQUE
                                                                            CO 15 1 HOO
      IF ( . AGT . FGS) GU TC 2
                                                                            CC151900
      CALL CUTESP
                                                                            C0152000
      FAS END OF RUN FLAG BEEN SET IN OUTPSP BY USER?
C
                                                                            C0152100
      IF (FCI) CU TO 2
                                                                            C0152200
    E CCATINUE
                                                                            C0152300
                                                                            C0152400
      SHOULD A HESTART TAPE BE MACE?
                                                                            C0152500
      IF (LETAFE) GO TO C
                                                                            C0152600
      CALL RETART (2.Y. YC. NEG. TEP.62)
                                                                            C0152700
    & CALL CUTPSP
                                                                            C0152800
    4 CONTINUE
                                                                            CO 152900
     LSER SHOULD WRITE CUTPUT CATA ON FILE 1 OF TAPE 11. HESTAFT CATA CO153000
C
         IS PLT INTO FILE 2 CF TAFE II
                                                                            C0153100
     LEGILD 11
                                                                           CO154200
                                                                            CO153300
         GC TO I TO SEE IF ANOTHER N-BODZ AUN FOLLUS
                                                                            C0153400
 . . . . . .
                                                                            (0153500
   2 STCP
                                                                           C0153600
 12C FORMAT (A4)
                                                                           C0153700
  101 FORMAT ('1')
                                                                           CO 15 380 C
                                                                           C0153900
  102 FORMAT (4x.17L1)
```

ENC C0154000

```
C
                                                                          00200000
      SLERCUTINE DYN(Y.YC.NEQ)
                                                                          00200100
C
                                                                          0200200
             DEFINES THE LOGICAL FATHS THROUGH THE SUBROUTINES USED TO (0200300
C
C
                 SET UP THE SIMULTANEOUS DIFFERENTIAL EQUATIONS
                   CF MCTION FOR THE COUPLED N-BODY SYSTEM
C
                                                                          00200500
C
                                                                          0000000
C
                                                                          C0200700
C
                                                                          00800500
      IMPLICIT HEAL+8(A-H.O-Z.1)
                                                                          00200900
      LOGICAL FG1. FG2. FG3. FG4. FG5. INERF. RBLO. LEQU. LINIT(1)
                                                                          C0201000
      LCGICAL
                       NETART, LETAPL
                                                                          001100
                                                                          C0201200
C
C
                                                                          00201300
      INTEGER
                                                                          C0201400
     * ANCHE . CTI
                     . CT2 . -CT3
                                      . CT4
                                              . CT5
                                                      . FCCN . PCCN
                                                                         00201500
                                      . SFKDUM. SFK
                                                              . SG
                    . SCRDUM. SCR
                                                    . SFR
     * SCNELM. SCN
                                                                         CO201600
             . SIG
                     . SIXDUM. SIX
                                      . SKDUM . SK
                                                      . SL
                                                              . SLK
                                                                          C0201700
                                      . SUK
     . SMA
             , SMCDLM, SMC , SMV
                                              . SPIDUM. SPI
                                                              . SUF
                                                                          00201800
                                     . SVA
                                                              . SVI
     * SCL
             . SR
                    . SSCN . SEIX
                                              . SVB . SVD
                                                                         CC201900
                                                             . SEU
     . SVM
             . SVP
                     . SVO . SXM
                                      . SXT
                                              . TURG
                                                     . SMAL
                                                                          0202000
                    . NFL XH . SFLX . SFXM . NMCDS . SFCC . SCC
     . 50
             . 560
                                                                         00202100
     * IINIT(1)
                     · IZINIT(1)
                                      . SD
                                                                          00202200
C
                                                                          00202300
·C
                                                                          00202400
. C
                                                                          C0202500
      FFAL .
                                                                          (0202600
                     . CAF
                             (3.10) . ETIC (3.10) . ETMC (3.10) .
     ANGE (33)
                                                                         00202700
     . FLQ
            (3,20) , FLE (3,3,20), FLH (3,3,20),
                                                                          008202800
                    . YMCD (3,2,11), HINIT (1)
                                                     . FZINIT(1)
     . THACO (33)
                                                                          00202900
                                                                          00203000
                                                                          00150500
C
      COMMON /CHEKS/
                              NSTART. LRTAPE
                                                                          C0203200
0
                                                                          C0203300
                                                                          00203400
C
      COMMEN /LOGIC/ FG1. FG2. FG3. FG4. FG5. INERF. ROLO(10)
                                                                         00203500
                                                                         C0203600
C
                                                                          00203700
                       ANORK (200)
      COMMEN /INTG/
                                                                          CC203800
                                      . CT3
                                                      . CT4
     . C11
                      · C12
                                                                          C0203900
     · C15
                      . FCON (23)
                                      . JCCN (13)
                                                      . LCUN
                                                              (22)
                                                                         C0204000
                     . Ne1
                                      . NOCD
                                                      . NCTC
     . ..
                                                                          00204100
                                      . NFRC
     . NFER
                      . NFKC
                                                      . NLOR
                                                                         00204200
     . NHV
                      . MMO
                                      . NMOA
                                                      . NSVP
                                                                          C0204300
                      . FCGN
                                                      . SFR
                                      . SD
     . NEVG
                                                              (33)
                                                                         C02C4400
                             (11)
                      . 51
                                                      . SL
     • SG
                              (55)
                                      . SIG
                                                                         00204500
                                                      . SOF
                     . SMA
                                      . SCK
    . . SLK
             (33)
                             (10)
                                              (11)
                                                              (11)
                                                                         00204600
     . SGL
                                      . SH
                                                      . SSCN
                                                                          C0204700
             (11)
                     . SHV
                                                      . SVD
                                      . SVB
     . SSIX
                      . SVA
                                                                         C0204800
                                      . SVP
                                              (22)
                                                      . SVQ
                                                              (33)
     · SVI
                      . SVM
                                                                         CC204900
                                      . TORU
                                                      . SMAL
                                             (97)
     . SXM
             (2.10)
                     . SXT
                                                                         C0205000
     . SEU
                     . ATQ
                                      . SC
                                              (33)
                                                      . SCG
                                                                         C0205100
     . NFLXB
                     . SFLX
                                      . SFXM
                                             (10)
                                                      . MMODS
                                                                         C0205200
                     . 500
                                                                         C0205300
     . SECC
                             (10)
```

```
1
C
                                                                       C0205400
C
                                                                       C0205500
     COMMEN /INTGZ/
                                                                       C02C5600
                    . SCN
                                                    . SCR
     * SCNEUM
                            (5)
                                   . SCROUM
                                                            (9)
                                                                       C0205700
     . SFKCLM
                    . SFK
                            (5)
                                    . SIXDUM
                                                    . S1x
                                                            (9)
                                                                       00205800
     * SKDLM
                    . SK
                                     . SPIDUM
                                                            (9)
                                                                      C02C5900
                            (5)
                                                    . SPI
     . SMCELM
                    . SMC
                             (5)
                                                                       C020600C
C
                                                                       C02C6100
C
                                                                       C0206200
     COMMEN /REAL/
                                                                       C0206300
     . .
            (3.10) . CAC
                            (3.10) . CLM
                                           (10)
                                                    . CLMC (3.11) .
                                                                       0206400
            (3.11) . ETC
                                                    . FUMC
                                                           (3.11) .
                                                                      C0206500
     . DEMC
                            (3.11) . ETM
                                            (33)
     . GAN
             (3.60) . +
                                    . HM
                                            (3.10)
                                                    . HMC
                                                            (3.10)
                                                                       00206600
                                                            (3.33) .
                                                    . GF
     . HACH
            (10)
                    . Fri
                            (2.11)
                                                                       C02067CC
                                    . PLM
                                            (10)
            (J.3J) . GL
                                                    . RCMC
                                                            (3.11) .
     * QFC
                            (3.22) . QLC
                                            (3.22)
                                                                      0206800
     * T
                                     THA
                                             (33)
                                                    . THAD (33)
                                                                       00206900
                                    . XDIC
     * THACH (10)
                   . THAM
                            (10)
                                            (3.3.66) . XI
                                                            (3.3.10) .
                                                                       00207000
                                    . XMN
     * XIC
            (3.3.10), XMAS
                            (10)
                                             (33,33) . XMT
                                                            (3.3.10).
                                                                       CO20710C
                             (3,20) . FLB
             (33) . FLA
                                                            (3.20) .
     . TUG
                                            (3,20) . FLC
                                                                       C0207200
     . FLD
            (3.3.20), FLJ
                             (3.3.20). CAO
                                            (3.10) . XIC
                                                            (3,3,10).
                                                                       (0207300
                                                                       C0207400
C
     * FLIRC (3.10) , FLCRC (3.10) , FLAC (3.20) , FLOC (3.20) .
                                                                       C0207500
                                                            (3.40) .
     * FLC# (20) , ZETA (20) , FCF
                                            (3.3.40) . FCK
                                                                       C02C760C
     . TIMENO
                                                                       C0207700
                                                                       C0207800
C
     CCHMCH /HEALZ/
                                                                       C0207900
     . CEDLM (1.3) , CE
                            (3.10) . C3CDUM(1.3) . CBC
                                                            (3.10) .
                                                                       C0208C00
     * XMCCLA(1.1.9) . XMC (3.3.13). CdN(3)
                                                                       00208100
C
                                                                       C0208200
C
                                                                       C0508300
     EQUIVALENCE (ETM(1). THADE(1))
                                           . (XMN(1.1). ANGD(1))
                                                                       C0208400
                 (XMN(1.3).YMCD(1.1.1))
                                           . (XMN(1.6).CNF(1.1))
                                                                       C0208500
                                                                  .
                  (XMN(1.8),ETIC(1.1))
                                            . (XMN(1.10).ETMC(1.1)) .
                                                                       00998000
                 (FLB(1.1).FLG(1.1))
                                            .(FLE(1.1.1).FLD(1.1.1)).
                                                                       C02C8700
     .
                  (FLH(1.1.1).FLJ(1.1.1))
                                                                       C0208800
                                           .(CA(1.1).HINIT(1))
                 (FGI.LINIT(1))
                                                                       C0208900
                 (CBDUM(1.1).FZINIT(1))
                                           . (AWCFK(1). IINIT(1))
                                                                       (0209000
                 (SCNDLW.IZINIT(1))
                                                                       C0209100
C
                                                                       00209200
                                                                       00209300
C
     DIMENSILA Y(NEQ) . YE(NEG)
                                                                       C0209400
     LOGICAL LG(33)
                                                                       C0209500
C
                                                                       C0209600
                                                                       C0209700
C
     COLNT TIMES THRU DYN
                                                                       00209800
C
     CT4 = CT4 + 1
                                                                       0209900
     CHECK FLE FIRST PASS
C
                                                                       CC210000
      IF (C14.61.1) GC TO 1
                                                                       C0210100
                                                                       00210200
C
C
     MAKE USE UF
                                                                       C0210300
         MMI = NUMINAL STATE TRANSFURMATION MATRICES
                                                                       C0210400
C
C
             # FREE CUCHDINATE VECTORS
                                                                       C0210500
          THA = INITIAL ROTATION ABOUT OF VECTOR
                                                                       C0210600
C
      TO COMPUTE THE INITIAL VALLES FUR THE COMPONENTS OF THE
                                                                       C0210700
G
      TRANSFORMATION MATRICES.
                                                                       C0210800
C
          *MC = TRANSFORMATION MATRIX WHICH TAKES VECTORS FROM
C
                                                                       C0210900
               BODY FIXED COORDINATES TO COMPUTING FRAME COORDINATES
                                                                       C0211000
C
     (ALL TRASIV(XMT, GF.THA.JCCA.PCJA.NBCD.RBLD.INERF.XMCDUM.XMC)
                                                                       CO211100
     GD TC 2
                                                                       C0211200
C
                                                                       CO211300
```

```
1 CONTINUE
                                                                         CO211400
C
                                                                         CO211500
     RETURN FERE AFTER INITIALIZATION PASS THROUGH DYN
C
                                                                         C021160C
        SORT CLT QUANTITIES IN ARRAY Y
C
                                                                         C0211700
      (ALL SETUPITY . YO . NEG. . TRUE . )
                                                                         CC211800
C
                                                                         00211900
     COMPLETE TRANSFORMATION MATRICES ARE NOT OBTAINED VIA INTEGRATION CO212000
C
         SIX OF NINE ELEMENTS IN EACH MATRIX HAVING LABEL IN SD DETAINEDCO212100
C
            BY INTEGRATION. FEMAINING CHES BY URTHUGONALITY
C
         MATRICES WITH LABELS NOT IN SD ASSUMED CHTAINABLE ALGEBRACIALLY CO212300
C
            DY SMALL ANGLE OF EULER ANGLE TECHNIQUES
     CALL THAN
                                                                         C0212500
C
                                                                         00212600
    2 IF (CT4.NE.1) GC TC 3
                                                                         C0212700
C
      FIRST PASS THROUGH
C
       TAKE INTO ACCOUNT SET SVO. CHLY THESE VECTORS AND DYADS WITH
                                                                        C0212900
C
       BOOY LABELS IN SET SVC ARE TO BE TRANSFORMED
                                                                         00213000
C
          COMPUTE OF AND OL VECTORS NUT DEFINED BY INPUT USING
                                                                        C0213100
           VECTOR CHOSS PRODUCT DEFINITION
                                                                        CO 21 3200
C
C
          CET ALL VECTORS AND EYACS INTO COMPUTING REFERENCE FRAME
                                                                        CO213300
          SET UP SETS WHICH SPECIFY EXACTLY WHICH VECTORS TO BE
C
                                                                         CO213400
C
            THANSFERMED FOR DE LOCPS IN TRANVO
                                                                         CC21 3500
     CALL VOIV
                                                                         00213600
C
      SET UP INITIAL VALUES FOR EQUATIONS AS THEY GO INTO RUNGE
                                                                         C0213700
      (ALL EGIV(Y.NEG)
                                                                         C0213800
      GO TC 4
                                                                         C0213900
C
                                                                         CC214000
     NOT FIRST PASS THROUGH
                                                                         C0214100
       TRANSFORM UNLY SELECTED VECTURS AND DYADS
C
                                                                         CO214200
      MAKE USE OF XMC TO TRANSFORM ALL BODY FIXED VECTORS AND DYAD INTO 00214300
C
      COMPUTING FRAME COORDINATES
C
                                                                        CC214400
           CAC = XMC+CA
                                       - CENTER OF MASS IN SET SVA
                                                                        CO214500
            CEC = XMC*CB
C
                                      - HINGE POINT IN SET SVB
                                                                        CO214600
C
            OFC = XMC+OF
                                      - FREE VECTOR IN SET SVO
                                                                        C021470C
                                      - LOCKED VECTORS IN SET SVP
C
            ULC = XMC+UL
                                                                        CO214800
            XIC = XMC+XI+(XMC)++(+1) - INERTIA UYAU IN SET SVI
C
                                                                        CO214900
            HMC = XMC+HM
                                      - WHEEL AXIS IN SET SVM
C
                                                                        CC215000
    3 CALL THANVO
                                                                         C0215100
    4 CCATINUE
                                                                         C0215200
                                                                         CO215300
C
      MAKE USE OF FREE VECTORS IN COMPUTING FRAME COURDINATES AND
                                                                         CC215400
      RATE ABOUT OR ALONG THEM TO DEFINE ALL HATE DEPENDENT TERMS
C
                                                                         CC215500
      CALL HATE
                                                                         C0215600
                                                                         CO215700
C
      MAKE USE OF TRANSFORMED EODY FIXED VECTORS AND DYADS TO CONSTRUCT CO215800
       THE MATRIX OF INENTIA AND FSULDO INERTIA TENSORS
                                                                         C0215900
C
                      CEMPUTE ELEMENTS.
                                                                         00216000
         FASS LNE -
C
                          SKIP ALL ZERO ELEMENTS
                                                                         CO216100
                          TRUNCATE SUMMATIONS USE SET SPI
                                                                        C0216200
C
      THERE-AFTER -
                      CEMPUTE ELEMENTS.
                                                                         00216300
C
                          SKIP ALL ZERO ELEMENTS
                                                                        CO216400
                          SKIP TIME CONSTANT ELEMENTS USE SET SXT
                                                                        C02165CC
C
C
                          TRUNCATE SUMMATIONS USE SET SPI
                                                                         C0216600
                                                                         CC2167C0
     CALL XDY
C
                                                                         CC216800
     MAKE USE UF VELOCITY AND ECCY FIXED VELTURS TO COMPUTE GYROSCOPIC CC216900
C
      CRESS COUPLING TERMS
                                                                         CC217000
                                                                        CO 21 71 00
C
           INERTIA CROSS COUPLING TRUNCATE ACCORDING TO SIX(1)
C
          CENTRIPITAL CROSS CELFLING TRUNCATE ACCORDING TO SCN(1)
                                                                        C0217200
                                                                        C0217300
           COMINGES CHOSS COUPLING TRUNCATE ACCORDING TO SCR(1)
```

```
MCMENTUM WHEEL COUPLING NOT THUNCATED
c
                                                                          C0217400
           FLEXIBLE BODY EFFECTS NOT TRUNCATED SET SFLX
                                                                          CO21 7500
C
     CALL ETA
                                                                          CO217600
c
                                                                          C0217700
      MAKE USE OF PUSITION AND RATE INFORMATION TO COMPUTE
C
                                                                          C0217800
      ALL NON-GYRCSCOPIC TOFCLES
                                                                          C0217900
C
     NOTE - SLBROUTINE TORQUE IS USER DEFINED (EMPTY IF NOT)
C
                                                                          C021800C
     (ALL TOFQUELY.YD. NEQ)
                                                                          C0218100
c
                                                                          C0218200
     PAKE USE UF PHEE COORDINATE VECTOR TO DOT VECTOR-CYADIC EQUATION COSISSOO
C
c
      OF MOTION TO GET ACCELERATIONS ABOUT FREE COORDINATE AXES
                                                                          C0218400
      ALSC SET UP AND EXPAND EQUATIONS TO ACCOUNT FOR VARIABLE SPEED
                                                                         C0218500
c
C
      MCMENTUN WHEELS AND FLEXIBLE HUDY EFFECTS
                                                                          C021 8600
     CALL GECLT
                                                                          C0218700
c
     EXIT FROM OFOOT WITH EQUATIONS OF MOTION IN SCALAR FORM
                                                                          C0218800
c
                                                                          00218900
C
            REDUCE THE CFOOT ECLATIONS TO OBTAIN THADD
                                                                          CC219000
    ENTER SING WITH ELEMENTS XMN AND ETH JUTAINED IN OFDOT
                                                                          C0219100
C
C
       EXIT WITH ACCELERATIONS THAUD, XMN DESTROYED IN SIMO
                                                                          C0219200
c
     EQUIVALENCE PUTS THADE AND ETM IN SAME STORAGE LUCATION
                                                                          00219300
C
                                                                          00219400
C
     CHECK TO SEE IF ANY DEGREES OF FREEDOM CAGED
                                                                          (0219500
      IF (SCG.NE.O) GU TO 5
                                                                          00219600
C
         NONE CAGED
                                                                          C0219700
      N = NFER+NMV+NMODS
                                                                          C0219800
     (ALL SIMC(XMN. THACC.N.33)
                                                                          C0219900
      GO TC &
                                                                          CC220C00
    5 CCATINUE
                                                                          C0220100
         CHE LA MURE CAGED DEGREES OF FREEDOM
C
                                                                          (0220200
         CELETE AND RENUMBER ROWS AND COLS OF XMN.ETM IN COMPRS
C
                                                                         C0220300
          SULVE REDUCED SET OF EGUATIONS IN SIMO
C
                                                                          00220400
         RESTRUCTURE THADE ARRAY PLUGGING IN ZERCS IN UMPRS
                                                                          C0220500
      N = NFEH+NMV+NMODS-SCG
                                                                          00220600
      (ALL CEMPRS(XMN.THADD.N.SC.SCG.LG)
                                                                          C02207CC
      (ALL SING(XMN.THACC.N.33)
                                                                          00220800
      (ALL UNPES(TEACD. N.SCG.LG)
                                                                          00220900
    & CONTINUE
                                                                          00221000
                                                                          C0221100
      CEFINE DIRECTION COSINE EQUATIONS IN ACCORDANCE WITH SET SD
C
                                                                          C0221200
      CALL DCT
                                                                          C0221300
C
                                                                          C0221400
C
      CEFINE ANGULAR PUSITION EQUATIONS ACCURDING TO SFR(I) AND SMA(I) C0221500
      CALL ANGLE
                                                                          C0221600
                                                                          C0221700
C
      FUT ALL FIRST CROEF EQUATIONS IN ONE DIMENSIONAL ARRAY ACCEPTABLE C0221800
      TO INTEGRATION ROLTINE FUNGE
c
                                                                          (0221900
      (ALL SETUP (Y.YD.NEG. . FALSE.)
                                                                          00222000
      IF(T.GE.TIMEND) GC TO 500
                                                                          C0222100
      SETUEN.
                                                                          00222200
C
                                                                          00222300
  SCC CONTINUE
                                                                          C0222400
      FG1 = .FALSE .
                                                                          C022250C
      FETURN
                                                                          00222600
      END
                                                                          C0222700
```

C

0000000

```
SLERCUTINE HSTART (J.Y.YC.NEG.TEN.*)
                                                                            00100500
C
                                                                            00300200
C
      ZERC DUT ALL ARRAYS OR FILL THEM IN FROM THE RESTART TAPE
C
                                                                           00300400
C
        AT THE END OF RUN CHEATE A RESTART TAPE. TO DO THIS
       FUT THE MESTART CATA IN FILE 2 UF TAPE 11
C
                                                                           0300600
C
                                                                           00300700
     NOTE: APPROPRIATE JOH CONTROL LANGUAGE MUST ACCOMPANY
C
                                                                           00300800
C
                                                                           0000000
     SUGGESTION: FILE I ON TAFE IC PREVIOUS OUTPUT DATA
C
                                                                           00010500
                   FILE 2 CN TAFE 10 RESTART CATA
C
                                                                           00301100
C
                   WITH A UTILITY ROUTINE CUPY FILE 1 OF TAPE 10
                                                                           00301200
                    ONTO FILE 1 OF TAPE 11. THEN PUT NEW OUTPUT DATA
C
                                                                           C0301300
                   RIGHT AFTER IT WITHOUT AN EUF MARK. TAPE 11 WILL THENCO301400
c
                   HAVE IN FILE 1 A CONTINUOUS RECORD OF THE OUTPUT
C
C
                   DATA FROM T=0
                                                                            00301600
C
                   AT END OF RUN NEW RESTART DATA FUT AFTER AN EGF MARK C0301700
                   ON TAPE 11. IT BILL THEN BE IN FILE 2 LF TAPE 11
C
                                                                           CC301800
c
                   CLD TAPE IC WILL BE UNDISTURBED
                                                                           00301900
C
                                                                           0002000
     IMPLICIT REAL+8(A-H.O-2.1)
                                                                           00302100
C
                                                                           0022200
      LOCICAL FG1, FG2, FG3, FG4, F35, INERF, RBLD, LEGU, LINIT(1)
                                                                           00302300
                       ASTART, LRTAPE
     LOGICAL
                                                                           0042000
C
                                                                           00302500
     INTEGER
                                                                           00302600
     * ABCRK , CT1 , CT2 , CT3 , CT4 , CT5 , FCON , PCON , 00302700
     * SCNEUM, SCN , SCRDUM, SCR , SFKDUM, SFK , SFR , SG , C0302800
* SI , SIG , SIXDUM, SIX , SKDUM , SK , SL , SLK , C0302900
                                      , SKDUM , SK , SL , SLK , C0302900
, SCK , SPIDUM, SPI , SUF , C0303000
, SVA , SVE , SVD , SVI , C030310C
     * SMA
             . SMCDUM. SMC . SMV
             . SR . SSCN . SEIX . SVA
     * SCL
             SVP , SVQ , SXM , SXT , TURQ , SMAL , SEU , C0303200 , SCG , NFLXB , SFLX , SFXM , NMUDS , SFCC , SCC , C0303300
            . SVP
     . SVM
     * SC
     • [INIT(1)
                     . IZINIT(1)
                                      . 50
                                                                           C0303400
C
                                                                           00303500
C
                                                                           00303600
     REAL .
                                                                           00303700
     • ANGC (33) . CNF (3,10) . ETIC (3,10) . ETMC (3,10) . C0303800

• FLQ (2,20) . FLE (3,3,20), FLH (3,3,20). C0303900
                                                      . RZINIT(1)
     . THACO (33)
                    . YMCD (3.2.11), RINIT (1)
                                                                           0000000
C
C
                                                                           00304200
     CCMMEN /CHEKS/
                              ASTART, LRTAPE
                                                                           CO 304300
C
                                                                           C0304400
C
                                                                           C0304500
     COMMEN /LUGIC/ FG1. FG2. FG3. FG4. FG5. INERF. ROLU(10)
                                                                           00304600
                                                                           CO 304700
C
                                                                           0084000
C
     COMMEN /INTG/
                       ANORK (200)
                                                                           00304900
                                      . CT3
                                                      . CT4
     * CT1
                     . CT2
                                                                          00205000
                     . FCON (33)
                                      . JCCN (10)
     * CT5
                                                      . LCUN (22)
                                                                        . 00305100
     * MC
             (10)
                     . NB1
                                      . NOOD
                                                       . NCTC
                                                                          00305200
     . NFER
                     . NFKC
                                     . NFRC
                                                      . NLOK
                                                                           C0305300
                     . NMO
                                      . NMUA
                                                      . NSVP
                                                                          C0305400
     * NAV
                                      . 50
                     . PCCN (11)
                                                      . SFR
                                                                       . 00305500
     . NEVC
                                                               (33)
                     . 51
                                                      . SL
                                                                       . 00335600
     . 56
                              (55)
                                     , SIG
                   . SMA
                             (10)
                                                      . SUF
     . SLK
                                     . SOK (11)
                                                               (11)
                                                                          00305700
             (33)
     * SCL
             (11)
                     . SMV
                                      . SH
                                                      . SSCN
                                                                          0.0305800
                     . SVA
                                                      . SVD
                                      . SVB
                                                                        . 0305900
     . SSIX
                                                      . SVG (33) . C0306000
     · SVI
                     . SVM
                                     . SVP (22)
```

```
. 00306100
     * SXM (2.10) . SXT
                                       . TORG (97)
                                                         . SMAL
                      . NTO
                                                         . SCG
     * SEU
                                       · SC
                                                (33)
     * NFL XU
                      . SFLX
                                        , SFXM (10)
                                                         . NMUDS
                                                                             C03063C0
     . SFCC
                      . scc
                               (10)
                                                                              004000
C
                                                                              00306500
C
                                                                              00306600
      CCMMCN /INTGZ/
                                                                              00306700
                      . SCN
                                       . SCRDUM
     * SCNEUM
                               (5)
                                                         . SCR
                                                                 (9)
                                                                             00800600
                      . SFK
                                       . SI'XDUM
                                                         . SIX
     * SFKCLM
                                                                 (9)
                                                                             0306900
                              (5)
     * SKOLM
                               (5)
                                       . SPIDUM
                                                         . SPI
                                                                  (9)
                                                                              0307000
                      . SK
     . SMCCUM
                      . SMC
                              (5)
                                                                              C0307100
C
                                                                              C0307200
                                                                              CO 307300
      COMMEN /FEAL/
                                                                              C03C7400
                                                         . COMC
                               (3.10) . CLM
                                              (10)
     . CA
             (2.10)
                      . CAC
                                                                 (3.11)
                                                                              C03C7500
     * DCMC
             (3,11) . ETC
                              (3.11) . ETM
                                               (33)
                                                         . FOMC
                                                                 (3.11)
                                                                              00307600
                                                                          .
                                       . HM
                                                        . HMC
     . GAN
             (3.60) . F
                                                (3,10)
                                                                 (3.10)
                                                                             00307700
             (10) • PHI
(3,33) • GL
                                                         . QF
                                                                 (3.33)
     . HNON
                               (3.11)
                                       . PLM
                                                (10)
                                                                             C0337800
                                                                          .
     * QFC
                               (3.22)
                                       . QLC
                                                (3.22)
                                                        . RCMC
                                                                 (3.11)
                                                                              CC30790C
                                                        . THAD (33)
     • T
                                        THA
                                                (33)
                                                                             00080000
                                                                          .
     * THACH (10) . THAW (10)
                                     , XDIC (3.3.66), XI
                                                                 (3.3.1C).
                                                                             00308100
             (3.3.10). XMAS (10)
                              (10) , XMN
(3,20) , FLB
                                                                 (3.3.10).
                                                                             00308200
     * XIC
                                                TMX . (EE.LL)
     * TUG (23) , FLA (3.20) , FLB (3.20) , FLC (3.20) , FLC (3.21) , FLD (2.3.20), FLJ (2.3.20), CAO (3.10) , XIO (3.3.10), FLIRC (3.10) , FLCRC (3.10) , FLAC (3.20) , FLQC (3.20) ,
                                                                              CC308300
                                                                              00490500
                                                                              C0308500
                    . ZETA (20)
     * FLON (20)
                                     , FCF (3.3.40), FCK
                                                                 (3.40) .
                                                                             00308600
     . TIMEND
                                                                              00786800
C
                                                                              0088000
                                                                              0098900
C
      CCMMEN /REAL Z/
                                                                              0000000
     * CEDLM (1.3) , CH
                              (3.1C) . CdCDUM(1.3) . CBC
                                                                 (3.10) .
                                                                              00309100
     * XMCCLM(1.1.9) . XMC
                               (2.3.10), CBN(3)
                                                                              00309200
                                                                              C0309300
C
      CCMMCN /SATELL/ DLMMY(1000)
                                                                              C0309400
                                                                              CO 339500
C
                                              .(XMN(1.1).ANGD(1))
                                                                              C0309600
      EQUIVALENCE (ETM(1).THACC(1))
                   (XMN(1.3), YMCD(1.1.1))
                                              . (XMN(1.6).CNF(1.1))
                                                                              C0309700
                   (XMN(1.8),ETIC(1.1))
                                               . (XMN(1.10).ETMC(1.11) .
                                                                              00309800
     .
                   (FLB(1.1), FLQ(1.1))
                                               ,(FLE(1.1.1),FLD(1.1.1)),
                                                                              00309900
     .
                   (FLH(1.1.1).FLJ(1.1.1))
                                                                              00001600
                                              .(CA(1.1).RINIT(1))
     ٠
                   (FG1.LINIT(1))
                                                                              00310100
                   (CBDUM(1.1).FZINIT(1))
                                              . (AWORK(1). IINIT(1))
                                                                              00310200
                   (SCNDUM, IZINIT(1))
                                                                              (0310300
                                                                              00401500
C
C
                                                                              C0310500
                                                                              00310600
C
      CIMENSICN Y(160) . YC(160) . TEM(2.160)
                                                                              00701500
C
                                                                              00801500
C
      COMMEN BLUCK SIZES
                                                                              00210900
      IDEM 4 = 10
                                                                              00011000
      ICEME = 724
                                                                              00311100
      IDEM . = 70
                                                                              00311200
      IDEM7 = 4354
                                                                              00311300
      IDEME = 168
                                                                              CO311400
      IDEMS = 1000
                                                                              C0311500
C
                                                                              00311600
      GO TC (1.2).J
                                                                              CO311700
C
      INITIALIZE ALL STORAGE LOCATIONS TO ZERO
                                                                             00311800
    1 CO 3 I=1.10EM7
                                                                             C0311900
    3 FINIT(1) = 0.00
                                                                             000212000
```

```
CO 4 1=1.1DEMS
                                                                             C0312100
    4 CUMMY(1) = 0.DC
                                                                             CO312200
      CC 1C I=1.IDEM8
                                                                             00312300
   10 FZINIT(1) = 3.00
                                                                             00312400
      CO 11 I=1. IDEM5
                                                                             00312500
   0 = (1)TIAII 11
                                                                             00312600
      CO 12 I=1. IDEM6
                                                                             00312700
   12 IZINIT(I) = 0
                                                                             0.0851500
      CO 13 I=1. IDEM4
                                                                             00312900
   13 LINIT(I) = . TRUE.
                                                                             C031 3000
      CO 14 I=1.160
                                                                             C0313100
      Y(1) = 0.00
                                                                             CO313200
      YC(1) = C.DO
                                                                             CO313300
      TEM(1.1) = 0.00
                                                                             CO313400
   14 TEP(2.1) = 0.00
                                                                             C0313500
      IF ( . NCT . NSTART) RETURN
                                                                             C0313600
                                                                             CO313700
c
      RESTART FUN LGAD ALL COMMON BLOCKS AND LOCAL ARRAYS FROM
                                                                             CO31 380C
         THE RESTART TAPE. TAPE 10 FILE 2
                                                                             CO313900
      FE AD (13.102) Y
                                                                             CC31 4000
      FEAD (10.102)
                    YD
                                                                             00314100
      READ(10.101) NEG
                                                                             00314200
      READ (10.102) (DUMMY(1). [=1.[DEM9]
                                                                             00314300
      FE40(10.102) (RINIT(I), I=1, IDEM7)
FE40(10,102) (RZINIT(I), I=1, IDEM6)
                                                                             C0314400
                                                                            CO314500
      READ (13.101) (| INIT(1). I=1.1CEMS)
                                                                            CO314600
      READ(10.101)(IZINIT(1).1=1.10EM6)
                                                                            CO314700
      HEAD (13.101) (LINIT(1).1=1.1CEM4)
                                                                            CO 31 4800
      ASTART = .FALSE.
                                                                            00314900
      FG1 = .TRUE.
                                                                            CC315000
C
      LPCATE TERMINATION TIME
                                                                            C0315100
      FEAD 103. TIMEND
                                                                            C031520C
C
      ALL CATA REQUIRED TO RESUME COMPUTATION HAS BEEN INPUTTED
                                                                            CC315300
C
        GC TC THE START OF THE INTEGRATION LOOP IN MAIN
                                                                            CO 31 5400
      FETUEN 1
                                                                            C0315500
C
                                                                            CO 31 5600
C
                                                                            00 31 5700
C
      FUT EUF MARK ON TAFE 11 10 SEPERATE RESTART DATA FROM OUTPUT CATA CO315800
         IN FILE 2 OF TAFE II FUT RESTART DATA
                                                                            C0315900
    2 ENC FILE 11
                                                                            CO316000
      #RITE(11.102)
                                                                            (0316100
      #RITE(11.102) YD
                                                                            00246200
      .RITE(11,101) NEG
                                                                            CO316300
      BRITE(11.102) (DLMMY(1).1=1.10EM9)
                                                                            CO316400
      *RITE(11.102)
                     (RINIT(1).1=1.1DEM7)
                                                                            00316500
      #RITE(11.102)
                     (RZINIT(I). I=1. IDEMB)
                                                                            00316600
      CC316700
      WRITE (11.101) (IZINIT(I). I=1.10EM6)
                                                                            CO316800
      BRITE (11.101) ( LINIT(1).1=1.10EM4)
                                                                            CO3169CO
      REST IN FEACE ALL DATA NEEDED TO RESTART JUB IS ON FILE 2, TAPE 1100317000
C
C
        FURTHERMORE CLD RESTART TAPE. TAPE 10 HAS NOT BEEN DESTROYED
                                                                            C0317100
                                                                            CO317200
  101 FORMAT (1628)
                                                                            C0317300
  102 FORMAT (EZIO)
                                                                            CO 31 74CO
  103 FORMAT(015.5)
                                                                            CO317500
      FETURN
                                                                            C0317600
      ENC
                                                                            CO317700
```

```
CC420000
C
                                                                 CC400100
     SUPRCLTINE INDS
                                                                 C0400200
C
                                                                 C04003C0
C
      ACCEPTS ALL INFORMATION NEEDED TO DEFINE BASIC N-BODY SYSTEM
C
                                                                 CC400400
C
        1) TCPOLUGY
                                                                 C0400500
C
         2) INERTIA CHARACTERISTICS
                                                                 C0402600
C
         3) CECMETRIC CHARACTERISTICS
                                                                 CC400700
C
         4) KINEMATIC TRANSFORMATION
                                                                  C0400800
         5) MCMENTUM WHEELS. GYHCSTATS
C
                                                                 C04C0900
C
        E) INITIAL CUNCITIONS
                                                                 CC401000
        7) FREE AND LOCKED COURCINATE AXES
C
                                                                 C0401100
C
        E) INTEGRATION STEP SIZE
                                                                 CC401200
C
                                                                 CO401300
C
       ******** INES INPLT CATA SETUP *********
                                                                 CC401400
                                                           FCRMATS C0 401 500
C
                                                           +CCDES C0401600
                                                           **** *** CC 401700
C
                                                                 CC401800
C
C
         NUCC
                                                            A 1 CO CO4 31900
                                                                 C0402000
C
  MESS(J)
                                                            B 105+00402200
C
  .
                                  PCGN(N)
                                                            C 1C1*C0402300
  .
       FBLC(N)
                    JCCN(A)
                                                XMAS (N)
C
  .
     ×1(1.1.N)
                  XI(1.2.N)
                                XI(1.3.N)
                                                            C 1 C2 + C0 402400
C
     *1(2.1.N)
                                XI(2.3.4)
                                                            D 102+00402500
C
                  XI(2.2.N)
                                XI (3.3.N)
                                                            D 102 * CC 402600
C
     ×1(3.1.N)
                  X1(3.2.N)
                                                            E 102+CC4C2700
C
  . XMT(1.1.N)
                 XMT(1.2.M)
                               XAT(1.3.W)
  * XMT(2.1.N)
                 XMT(2.2.N)
                               XAT(2.3.4)
                                                            F 102 + C0402800
C
C
  * XPT(3.1.N)
                 XMT(3.2.N)
                               XMT(3.3.N)
                                                           E 102 + C0402900
C
       CA(1.N)
                    (A(2.N)
                                  CA(3.N)
                                                           F 102+00403000
C
       CE(1.N)
                    CB(2.N)
                                  CB(J.N)
                                                           G 102+C0403100
      GF (1. F)
                    QF (2. N)
                                  OF (3.4)
                                                           F 102# C0403200
C
  .
     GF (1. P+2)
                  OF (2. M+2)
                                JF (3, #+2)
                                                            ► 102*C0403300
C
  ∗ ₹
C
       THA( M)
                   THA(M+1)
                                 THALM+21
                                                           H 102+00403400
C
       THACENI
                  THAD(M+1)
                                THAD(M+2)
                                                            F 102+C0403500
C
  .
       GF (1. N)
                    QF (2.M)
                                  OF (3.M)
                                                            1 102*00403600
    GF (1.W+1)
                  QF (2. M+1)
                                OF(3.8+1)
                                                            I 102+C0493700
C
C
       THA(N)
                  THA(M+1)
                                                            1 102 - 00403800
C
       THAC(N)
                  THAC (M+1)
                                                            1 102000403900
       GF(1.)
                    GF (2. N)
                                  QF (3.M)
                                                            J 102+CC404000
C
  .
       CL(I.L)
                                                            J 102 + CO404100
C
                    GL(2.L)
                                  UL(J.L)
C
       THALMS
                                                            J 102 * CO 404200
C
  .
       THADINI
                                                            J 102 + C0424300
C
       GL (I.L)
                    CL(2.L)
                                  QL(3.L)
                                                           K 102*C0404400
C
    GL (1 .L+1)
                  UL (2.L+1)
                                OL(3.L+1)
                                                            K 102+00404500
  C
                                                                 CC404700
                                                           L 100 CC404800
C
  PCCA(ABCD+1)
       THAD(N)
                  THAC (M+1)
                                THAD(M+2)
                                                           M 1C2 C0404900
C
                                                           N 102 C0405000
       THAD(N)
                  THAD(M+1)
C
C
       THAC(N)
                                                           0 102 00405100
C
          NMC
                                                           P 1CC C0405200
                                                               C04053C0
C
  C
                                HM(2.1)
                  HK(1.1)
                                              HP (3.1)
                                                           0 104+00435500
       MU(I)
C
       PLM(I)
                    WESS(J)
                                                           H 106#00405600
                   THAD . (1)
                                                            S 102+C0405700
C
      THA.(1)
  C
                                                                 C0405900
```

C	SOIT GRANIT	C0406000
C		C0406100
C	******** END OF CATA CALLED FOR BY INBS ************************************	CC406200
C		C0406300
C	CCDE LIST	C0406400
C		C0406500
C	A - ALAAYS READ. FIRST CARD READ BY INSS	C0406600
C	NOUDETOTAL NUMBER OF BUDDIES (RIGID+FLEXIBLE+POINT MASSES)	C0406700
C		C0406800
(E - FIRST CARD FOR EACH SET OF BUDY DESCRIPTION CARDS	C0406900
C	N=3UDY NUMBER (SETS TO BE READ SEGUENTIALLY N=1.2	CC407000
(MLSS(J)=ANY ALPHANUMERIC MESSAGE WILL BE PRINTED AS A FEADING	
C	FOR BODY N IN THE INPUT GATA ECHU. PRINTED BY INBS	C0407200
C		C0407300
C	C - SECUND CARD FOR EACH SET OF BODY DESCRIPTION CARDS	C040740C
C	JCCN(N) = HUDY LABEL OF ECDY CONTIGUOUS TO AND INGOARD OF	CO437500
C	HODY N. HINGE FOINT BETWEEN BODIES JOON(N) AND N	CC4C7600
C	IS DEFINED AS HINGE PUINT N-1, IF N=1 THEN JCGN(1)=0	
C	AND FINGE PCINT O IS THE CENTER OF MASS OF BCDY I	C0407800
C	HOLD (N) = TRUE - IF HODY N A RIGID OR FLEXIBLE HODY	CO4C7900
C	.FALSE. IF EODY N A POINT MASS POON(N)=TOTAL NUMBER OF RIGIDLY CONSTRAINED RUTATIONAL	CO40810C
C	DEGREES OF FREEDOM AT HINGE POINT N-1 OF BODY N	C0438200
C	XMAS(N)=TOTAL MASS OF ECDY N AND ALL INSEDDED WHEELS(IF ANY)	
C	Additional and the state of the	(0408400
ć	C - LELETE THESE 2 CARDS IF BODY N A POINT MASS	C04C8500
C	XI(I, J, N) = INERTIA TENSOR OF BODY N BITH ALL DESPUN BREELS	C0408600
(INCLUED (IF ANY) ABOUT ITS UNN CENTER OF MASS AND	C0428700
C	RELATIVE TO THE BUDY N FIXED REFERENCE FRAME. IF BODY	
C	N IS FLEXIBLE INPUT INERTIA TENSOR IN UNDEFCRMED	C04C8900
(ZENU INTERNAL STRESS STATE	0009000
(0019100
C	E - DELETE THESE 3 CARDS IF BUDY N A PUINT MASS	00409200
	>M1(1,J,N) = THANSFURMATION MATRIX WHICH TAKES VECTORS FROM THE	C040930C
\subset	BUDY N TO THE EODY JCLN(N) FIXED REFERENCE FRAMES	CO409400
C	FCH ZERO RELATIVE ANGULAR ROTATION BETWEEN THE ECCIES	
C	IF HODY N IS A PUINT MASS THE BODY N FIXED REFERENCE	
(FRAME AXES ARE RESPECTIVELY PARALLEL TO THESE OF THE	
C	BUDY JCCN(N) FIXED REFERENCE FRAME	C0409800
(IF BODY N IS A FLEXIBLE BODY IT IS ASSUMED TO BE CLAMPED IN TRANSLATION AND RUTATION AT THE ORIGIN	C04C9900 C0410000
C	OF THE HODY N FIXED REFERENCE FRAME.	CO410100
C	or the hour of rived beforence roams.	CO410200
C	F - ALMAYS ALAD	CO410300
c	CA(I.N)=CENTER OF MASS VECTOR COMPONENTS OF THE VECTOR FROM	C0410400
C	THE HINGE POINT N-1 (UNIGIN OF BODY N FIXED REFERENCE)	
-	TO THE CENTER OF MASS OF BODY NUNDEFORMED POSITION	C0410600
(IF BODY N FLEXIBLE) RELATIVE TO BUDY N FIXED	C0410700
C	REFERENCE FRAME, FUR N=1 CA(1.N)=0 I=1.2.3 SINCE BY	C0410800
(DEFINITION THE HINGE POINT OF EGDY I IS THE CENTER	C0410900
C	OF MASS UF EDDY 1	CO411000
C		CO 41 1 100
C	C - ALAAYS HEAD	C0411200
\mathbb{C}	C3(1.N)=HINGE VECTOR. COMPONENTS OF THE VECTOR FROM HINGE	CO411300
C	POINT JCON(N)-1 TO HINGE POINT N-1 RELATIVE TO THE	CO411400
C	BUDY JCCN(N) FIXED REFERENCE. FOR N=1 IT IS THE	CO411500
C	VECTOR FROM THE INERTIAL DRIGIN TO THE CENTER OF	CO411600
C	MASS OF BUDY 1. WHICH IS THE INGE POINT OF BODY 1.	CO411700
C	RELATIVE TO THE INERTIAL REFERENCE FRAME	C0411800
C		CO411900

```
H - READ UNLY IF 3 DEGREES OF RELATIVE FREEDOM AT HINGE POINT N-1 CO412000
C
                                                                           CO412100
C
      1 - FEAC CNLY IF 2 DEGFLES OF RELATIVE FREEDOM AT HINGE POINT N-1 C0412200
C
                                                                           C0412300
C
C
      J - READ ONLY IF 1 DEGREES OF RELATIVE FREEDOM AT HINGE POINT N-1 CO412400
C
                                                                            CO412500
      K - FEAD UNLY IF C DEGREES OF HOLATIVE PREEDOM AT HINGE POINT N-1 CC412600
C
           GF(I.M)=COMPENENTS OF FREE COURDINATE VECTOR M
                                                                           CO412700
C
          GL(1.L) = CCMPCNENTS OF LOCKED COURDINATE VECTOR L
                                                                           C0412800
C
C
            THA(M) = RELATIVE DISPLACEMENT ABOUT OR ALONG OF (I.M)
                                                                           CO412900
           THAC(M) = RELATIVE RATE OF DISPLACEMENT ABOUT OF ALONG OF(1. ) CC413000
C
                   FREE AND LUCKED CUURINATE VECTORS ARE INPUTTED
C
C
                   RELATIVE TO THE BUDY FIXED PRAME IN WHICH THEY
                                                                           CC413200
C
                   ARE FIXED, WHEN FIXED IN BOTH BODY N AND BEDY JCGN (N) 00413300
C
                   THEY ARE INFLITED IN BODY JCCN(N) CCCRDINATES
                                                                           CO413400
C
                                                                           CO413500
C
     L - ALMAYS READ
                                                                           CO413600
C
     FCCN (NOUD+1) = NUMBER OF CONSTRAINED DEGREES OF TRANSLATIONAL
                                                                           CO 41 3700
C
                   FREEDEM FOR TOTAL SYSTEM
                                                                           C0413800
                                                                           CO413900
C
C
      . - READ UNLY IF 3 DEGREES OF TRANSLATIONAL PREEDOM FOR SYSTEM
                                                                           CC414000
                                                                           CO414100
C
C
     N - READ ONLY IF 2 DEGREES OF THANSLATIONAL PREECOM FOR SYSTEM
                                                                           CO4142CO
                                                                           CO414300
C
     C - READ ONLY IF I DEGREES OF TRANSLATIONAL FREEDOM FOR SYSTEM
C
                                                                           CC414400
C
           THAC(M) = INITIAL TRANSLATIONAL RATE ALCNG INERTIAL AXIS I
                                                                           C0414500
C
         THAU(H+1) = INITIAL TRANSLATIONAL RATE ALUNG INERTIAL AXIS 2
                                                                           C0414600
C
         THAD(M+2) = INITIAL TRANSLATIONAL MATE ALJNG INERTIAL AXIS 3
                                                                           C0414700
C
                                                                           CO414800
C
      F - ALWAYS READ
                                                                           CO414900
C
               NMOSTOTAL NUMBER OF SYMMETRIC WHEELS
                                                                           C0415000
C
                                                                           CO415100
C
     C - ALWAYS HEAD ( NMC . NE . C)
                                                                           C0415200
C
             MC(1) = BODY LABEL OF ECDY IN WHICH WHEEL I IS IMBEDDED
                                                                           CO4153CO
           HM(J,I)=COMPENENTS OF A UNIT VECTOR ALENG WHEEL SPIN AXIS
C
                                                                           CC415400
C
                   IN BCCY MC(I) FIXED COCHDINATES
                                                                           CO415500
                                                                           CC415600
C
     F - ALMAYS READ (NHO.NE.C)
C
                                                                           CC415700
           MESS(J) =MESSAGE TO EE PRINTED WITH WHEEL I DATA ECHO
C
                                                                           00415800
C
            PLM(1) = SPIN INFRTIA OF WHEEL I
                                                                           CO415900
C
                                                                           C0416000
C
     S - ALAAYS HEAD ( NAC. NE. C)
                                                                           C0416100
            THAN(I)=INITIAL WHEEL ANGLE
C
                                                                           CC416200
C
          THANC(1)=INITIAL WHEEL HATE
                                                                           CO416300
C
                                                                           C0416400
C
     T - ALAAYS HEAD
                                                                           C0416500
C
                 HEINTEGRATION STEP SIZE
                                                                           C0416600
C
            TIMENDETIME AT WHICH RUI IS TO BE ENDED
                                                                           C0416700
C
                                                                           C0416800
      100 FCHNAT(15)
                                                                           CC416900
C
C
      101 FURNAT(L5.215.(15.5)
                                                                           CO417000
      102 FURNAT (3015.5)
                                                                           C0417100
C
C
      104 FGRMAT(15.3015.5)
                                                                           CO417200
      105 FURNAT (15.1844)
                                                                           CC417300
C
C 106 FURMAT(C15.5.1644)
                                                                           C0417400
                                                                           CC 41 7500
C
                                                                           CO417600
      IMPLICIT REAL+B(A-H.G-Z.1)
                                                                           C0417700
     LOGICAL FG1. FG2. FG3. FG4. F35. INERF. RBLU. LEQU. LINIT(1)
                                                                           C0417800
     LCGICAL
                       METART. LRIAPE
                                                                           CC417900
```

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C
                                                                           CC418000
c
                                                                           CO418100
     INTEGEN
                                                                           CO418200
     * ABCRK , CT1 . CT2 . CT3 . CT4 . CT5 . FCCN . FCON .
                                                                          CO418300
     SCNCUM. SCN . SCRDUM. SCR . SFKDUM. SFK . SFR . SG
                                                                         CO 41 8400
                                    . SKOUM . SK
                                                      . SL
                                                              . SLK
            . 516
                     . SIXDUM. SIX
                                                                          CO41 8500
                                                              . SQF
     . SHA
             . SMCDUM. SMC . SHV
                                      . SOK . SPIDUM. SPI
                                                                          CC41 8600
                                                              . SVI
             . SR . SSCN . SSIX . SVA
                                              . SVB . SVD
                                                                          CC418700
            . SVP
     * SVM
                     . EVU . EXP
                                     . SXT . TCRQ . SMAL . SEU .
                                                                         CO418800
             . SCG . NFLXB . SFLX . SFXM . NMGDS . SFCC . SCC .
                                                                         C0418900
     . SC
     · IINIT(1)
                     . IZINIT(1)
                                     . SC
                                                                           CC419000
                                                                          C0419100
C
c
                                                                          CO419200
     SEAL .B
                                                                          C0419300
     * ANCC (33) . CNF (3.10) . ETIC (3.10) . ETMC (3.10) . C0419400

* FLQ (3.20) . FLE (3.3.20). FLH (3.3.20). C0419500
                    . YMCD (2.2.11). RINIT (1) . HZINIT(1)
     * THACO (34)
                                                                          CC4196CO
C
                                                                          C0419700
C
                                                                          C0419800
     CONMEN /CHEKS/
                              ASTART, LRTAPE
                                                                          CO419900
C
                                                                          C0420000
C
                                                                          C0420100
     (OMMEN /LUGIC/ FG1. FG2. FG3. FG4. FG5. INEMF. RELU(10)
                                                                          CC42020C
C
                                                                          C0420300
C
                                                                          C0420400
     CCHMEN /INTG/
                       ANORK (200)
                                                   . CT4
                                                                          C0420500
     * CT1
                     . CT2
                                     . CT3
                                                                      . 00420600
                     . FCON (33)
                                     . JCGN (10)
                                                      . LCUN (22)
     . C15
                                                                         C0420700
     . MC
                     . NEI
                                     . NOUD
                                                      . NCTC
                                                                         C0420800
            (10)
                     . AFKC
                                                      . NLUK
     . NFER
                                     . NERC
                                                                          C0420900
                                                      . NSVP
                     . AMO
                                     . NHUA
     . ...
                                                                         C0421000
                                    . 50
                                                      . SFR (33)
     . NSVC
                     . PCCN (111)
                                                                         C0421100
     . SC
                     . 51
                              (55)
                                     . 516
                                                      . SL
                                                                          C0421200
                                     . SCK (11)
                                                      . SQF (11)
                     . SMA
     . SLK
            (33)
                              (1C)
                                                                         C0421300
     • SCL (11)
                     . SMV
                                     . SR
                                                      . SSCN
                                                                         C0421400
                     . SVA
                                     . SVB
                                                      . SVC
     . SSIX
                                                                         CC421500
                                                      . SVG
                                     . SVP
     . SVI
                     . SVM
                                              (22)
                                                              (23)
                                                                          C0421600
                                                      . SMAL
     * SXM (3.10) . SXT
                                     . TONG (97)
                                                                      . 00421700
                     . . 10
                                     . SC
                                                     . SCG
                                                                       . CO421800
     . SEU
                                              (33)
                                                                       . C0421900
     . NFL H
                     . SFLX
                                      . 3FXM (10)
                                                    . MMODS
                     . SCC (10)
     • SFCC
                                                                          CC422000
                                                                          00422100
C
C
                                                                          CC422200
     CCHMCH / INTGZ/
                                                                          C0422300
                                     . SCRDUM
                                                    · SCR
     * SCNELM . SCN
                             (5)
                                                              (9)
                                                                         C0422400
                                     . SIXDUM
                                                                      . 00422500
     . SFKCUM
                     . SFK
                             (5)
                                                              (9)
     . SKOLM
                    . SK
                             161
                                     . SPIDUM
                                                     · SPI
                                                             (9)
                                                                      . C0422600
     . SHCEUM
                    . SHC
                             (5)
                                                                          C0422700
C
                                                                          C04228C0
                                                                          C0422900
0
     CCHMCN /FEAL/
                                                                          CO 42 3000
                             (3.10) . CLM (10) . CCMC (3.11) . 00423100
(2.11) . ETM (33) . FCMC (3.11) . 00423200
. HM (3.10) . HMC (3.10) . 00423300
(2.11) . PLM (10) . QF (3.22) . 00423400
    • CA (2.10) . CAC
• DCMC (2.11) . ETC
• GAM (2.00) . F
     • HNCN (10) , PHI (3.11) , PLM
• QFC (3.33) , GL (3.22) , QLC
                                            (3.22) , RCMC (3.11) , 00423500
(33) , THAD (33) , C0423600
                                      THA
                                                              (3.3.10).
                    . THAW (10)
                                     . XDIC (3.3.60). XI
     . THACW (10)
                                                                         CC423700
     * XIC (2.3.10). XMAS (10)
                                     . XMN ( ( LS. 23) . XMT
                                                             (3.3.10). 00423800
     • TLG (33) • FLA (3.20) • FLB (3.20) • FLC (3.20) • C0423900
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• FLD (3.3.20), FLJ (3.3.20), CAU (3.10) , XIU (3.3.10), CC424000
• FLIRC (3.10) , FLCRC (3.10) , FLAC (1.20) , FLQC (3.20) , C0424100
                    . ZETA (20) . FCF .3.40). FCK
     * FLC  (20)
                                                               (3.40) . 00424200
     . TIMEND
                                                                            C0424300
                                                                            CC424400
                                                                            C0424500
C
                                                                            C0424600
      CCHMIN /FEALZ/
                             (3.1C) . CSCOUM(1.3)
                                                                (3.10) .
                                                                           C0424700
     • CBCLM (1.3) . CP
                                                        · CAL
                             (3.3.10). CBN(3)
     . XMCCLM(1.1.9) . XMC
                                                                            C0424800
C
                                                                            C0424900
                                                                            C0425000
                                               .(XMN(1.1).ANGU(1))
      EQUIVALENCE (LTM(1). THACC(1))
                                                                            C0425100
                   (XMN(1.3).YFCC(1.1.1))
                                              . (XMN(1.6).CNF(1.1))
                                                                            (0425200
                   (XMN(1.8).ETIC(1.1))
                                               .(XMN(1.10).ETMC(1.1))
                                                                            C0425300
                                              .(FLE(1.1.1).FLD(1.1.1)).
                   (FLB(1.1).FLG(1.1))
                                                                            C0425400
                   (FLH(1.1.1).FLJ(1.1.1))
                                                                            C0425500
                   (FGI.LINIT(I))
                                               .(CA(1.1).HINIT(1))
                                                                            C0425600
                                              . (ABORK(1). IINIT(1))
                   (CHDUM(1.1).HZINIT(1))
                                                                            C0425700
                                                                            C0425800
                   (SCNOLW. IZINIT(1))
                                                                            CC425900
C
C
                                                                            00426000
                                                                            C042610C
C
C
                                                                            00426200
      CIMENSILN TEM1(3.2). TEM2(3.2)
                                                                            C0426300
      INTECEH MESS(18)
                                                                            C0426400
                                                                            C0426500
C
                                                                            C0426600
C
      . = 1
                                                                            C0426700
      L = 1
                                                                            C0426800
C
      NBCD = NUMBER OF ECDIES
                                                                            C0426900
      READ 13C. NEGD
                                                                            CC427000
      NB1 : NECD+1
                                                                            C0427100
      FRINT 195
                                                                            C0427200
      FRINT 200. NOCO
                                                                            C0427300
      FRINT 254
                                                                            C0427400
      PRINT 255
                                                                            C0427500
      PRINT ¿tt
                                                                            C0427600
                                                                            C0427700
      PRINT 257
      FRINT 25E
                                                                            CC42780C
      FRINT 255
                                                                            C0427900
      FRINT ZEC
                                                                            00085400
      READ INPLT FOR EACH BOCY
                                                                            CC428100
C
      CO 1 K=1.NBOD
                                                                            C0428200
      K1 = K-1
                                                                            C0428300
      MESS(J) = ALPHANUMERIC DESCRIPTION OF BODY N TO BE FRINTED
                                                                            C0428400
      READ 105. N. (MESS(J).J=1.18)
                                                                            C0428500
      IF (N.EU.K) GU TO 24
                                                                            C0428600
      FRINT 247
                                                                            CC428700
      1YFE 247
                                                                            20428800
C
                                                                            C0428900
      SE TUEN
   24 CONTINUE
                                                                            CC429000
      ROLC(K) = TRUE IF BODY & RIGID BUDY
C
                                                                            C0429100
              = FALSE IF BODY K PCINT MASS
                                                                            (0429200
C
      JCCN(K) = BUDY LAREL TO WHICH BUDY K IS ATTACHED AT HINGE K-1
C
                                                                            C042930C
     FCCN(K) = NUMBER OF CONSTRAINID AXES AT HINGE PUINT K-1
                                                                            C0429400
C
      XMAS(K) = TOTAL MASS OF EODY K PLUS MEMENTUM WHEELS
                                                                            C0429500
      READ 101. RULD(K).JCON(K).PCON(K).XMAS(K)
                                                                            C0429600
      IF (RELJ(K)) GU TO 2
                                                                            C0429700
                                                                            00429800
      FRINT 201. K. (MESS(J).J=1.18)
      FRINT ¿CE.K. XMAS(K)
                                                                            C0429900
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GO TC 3
                                                                           CC430000
    ¿ FRINT 202. K. (MESS(J).J=1.18)
                                                                           CO430100
      FRINT 2CE. K.XVAS(K)
                                                                           C0430200
      xI(I,J.K).I.J=1.3 = CCMFCNENTS OF INERTIA TENSOR OF BODY ( BITH
                                                                           C0430300
C
                            ALL DESPUN MOMENTUM WHEELS IN BODY K
                                                                           C0430400
                                                                           00430500
C
                    MASS RELATIVE TO BODY K FIXED FRAME
                           CODECINATES CABOUT THE COMPOSITE CENTER CF
                                                                           C0430600
C
      READ 102. ((XI(I...K).J=1.3).1=1.3)
                                                                           C0430700
      FRINT 21c. (XI(1.J.K), J=1.3). K
                                                                           C0430800
      FRINT 217. (XI(2.J.K).J=1.3)
                                                                           CC430900
      FRINT 216. (X1(3.J.K).J=1.3)
                                                                           CC431000
    3 CONTINUE
                                                                           C0431100
      1F (K .EQ . 1) GO TO 4
                                                                           C0431200
      FRINT 203. K.JCON(K).KI
                                                                           C0431300
      GC TC 5
                                                                           C0431400
                                                                           00431500
    4 FRINT 2C4
      PRINT 262. NBGD
                                                                           C0431600
                                                                           C0431700
    5 CONTINUE
      IF (.AJT. ABLOKA) GC TO 8
                                                                           C0431800 ·
      XMT(1.J.K).1.J=1.3 = CCMFCNENT OF TRANSFORMATION MATRIX BODY
C
                                                                          C0431900
                                                                           C0432000 . .
                           K TC BCDY JCON(K) CUDROINATES
      FEAD 132. ((XMT(1.J.K).J=1.3).[=1.3)
                                                                           C0432100
                                                                           C0432200
      GO TC 4
    E xM1(1.1.K) = 1
                                                                           C0432300
      MM1(1.2.K) = 0
                                                                          00432400
      *MT(1.3.K) = 0
                                                                          C0432500
      xMT(2.1.K) = 0
                                                                          CC432600
      XM1(2.2.K) = 1
                                                                          C0432700
      MI(2.3.K) = 0
                                                                           (0432800
      MT(3.1.K) = 0
                                                                           C0432900
      MT(2.2.K) = 0
                                                                           CC433000
                                                                           C043310C
      *** (3.3.K) = 1
    5 FRINT 219. (XMT(1.J.K).J=1.3)
                                                                           C0433200
      FRINT 226. K.(XMT(2.J.K).J=1.3)
                                                                          C0433300
      IF (K.E3.1) GO TO 10
                                                                           C0433400
      PRINT 222. JCON(K).(XMT(3.J.K).J=1.3)
                                                                           C0433500
      GO TC 11
                                                                           C0433600
                                                                          CC433700
   1C PRINT 221. (XMT(3,J.K),J=1,3)
   11 CONTINUE
                                                                           C043380C
      (A(J.K).J=1.3 = CCMPONENTS CF CENTER OF MASS FRCM HINGE PCINT K-1 C0433900
      FEAD 132. (LA(J.K).J=1.3)
                                                                           CC434100
      FRIN1 207. CA(1.K). K
      FRINT ¿CE. KI.CA(2.K)
                                                                           C0434200
      FRINT 2CS. K.CA(3.K)
                                                                           COA 44 300
      (B(J.K), J=1,3 = CEMPONENTS OF VECTOR FROM HINGE POINT (JCCN(K)-1) CC434400
C
                      HINGE POINT K-1 IN BODY JOGN(K) COGRDINATES
                                                                           C0434500
                                                                           C043460C
     READ 102. (C2(J.K).J=1.3)
      IF (K.NE.1) 60 TO 6
                                                                           00434700
                                                                          C0434800
      PRINT 21C. CH(1.K)
                                                                           CC434900
      PRINT 211. Cd(2.K)
      FRINT 212. C8(3.K)
                                                                           C043500C
                                                                          C0435100
      GO TC 7
                                                                          CC4352CO
    E K2 = JCCN(K)-1
                                                                           C0435300
      PRINT 213. CH(1.K).JCCN(K)
      FRINT 214, K2,CB(2,K)
                                                                          C0435400
      FRINT 215. KI.CH(3.K)
                                                                          C0435500
    7 CONTINUE
                                                                          C0435600
C
      READ IN FREE AND LOCKED COORDINATE VECTORS ALONG WITH INITIAL CONDCO435800
C
                                                                          C04359C0
      IF (K.EQ.1) GC TO 12
```

```
A = A + 3 - PCCN(K-1)
                                                                            C0436000
      L = L + FCUN(K-1)
                                                                            C0436100
   12 M1 = M+1
                                                                            C0436200
      W2 = W+2
                                                                            C0436300
      L1 = L+1
                                                                            C0436400
      L2 = L+2
                                                                            C0436500
      IF (RELUCKI) GO TO 20
                                                                            C0436600
      IASIGN = 1
                                                                            CO436700
      60 TC 21
                                                                            C0436800
   2C IASIEN = 0
                                                                            C0436900
                                                                            C0437000
   21 CENTINUE
      IGETE = FCJN(K) + 1
                                                                            C0437100
      GO TC (13.14.15.17). IGCTC
                                                                            C0437200
                                                                            C0437300
C
      FCCN(K) = 0. THREE DEGREES CF FREEDOM
                                                                            C0437400
   13 READ 132. ((OF(J.1).J=1.3).I=M.M2.2)
                                                                            C0437500
      RE #D 102. (THA(1).1=P. #2)
                                                                            C0437600
      FEAD 132. (THAD(1).1=M.M2)
                                                                            C0437700
      FRINT 246. KI
                                                                            C0437800
      IF (RELC(K)) GO TO 31
                                                                            C0437900
      FCCN(M) = K
                                                                            C0438200
      FCCN(MI) = K
                                                                            COARRIGO
      GD TC 32
                                                                            C0438200
   31 FCCN(N) = JCCN(K)
                                                                            C0438300
      CF(1.M1) CCMPUTED FRCM OF(1.M) AND OF(1.M2)
                                                                            C0438400
         FCCN(MI) = -M FELPS LCGIC IN SUBFCUTINE TRANVO
                                                                            C0438500
                                                                            C0438600
      FCCN(MI) = -M
   32 FCCN (N2) = K
                                                                            CC438700
      FRINT 226. UF(1.M).OF(1.M2)
                                                                            C0438800
      FRINT 225, M.QF(2,M),M2,QF(2,M2)
                                                                            C0438900
      1F (K.EG. 1) GO TO 29
                                                                            C0439000
      FR (NT 23C. FCON(M). GF(3.F).FCON(M2).GF(3.M2)
                                                                            C0439100
      GC TC 30
                                                                            C0439200
   25 PRINT 223.
                         GF (3. F) . FC3N(M2) . QF (3. M2)
                                                                            0019100
   3C CONTINUE
                                                                            C04394C0
      FRINT 263. MI
                                                                            C043950C
      IF (14516h .EG. 0 ) PRINT 224
                                                                            C0439600
      IF (IASIGN .EG. 1 ) PRINT 243
                                                                            C0439700
      FRINT 225, (1.THA(1).1.THAC(1).1=#.M2)
                                                                            C0439800
      FRINT 226
                                                                            CC439900
      CC TC 1
                                                                            000004000
                                                                            C0440100
      FCCN(K) = 1. TWO CEGREES OF FREEDOM
                                                                            C0440200
                                                                            C0440300
   14 READ 132. ((QF(J.1).J=1.3).[=M.M1)
      READ 132. THA(M) .THA(MI)
                                                                            CO 44 04 00
      READ 132. THAD(M). THAC(M1)
                                                                            C0440500
      FRINT 227. KI
                                                                            C0440600
      IF (RELUCK)) GC TU 33
                                                                            C0440700
      FCCN(M) = K
                                                                            C0440800
      FCCN(MI) = K
                                                                            C0440900
      LCCN(L) = K
                                                                            CC441000
      60 TE 34
                                                                            CO441100
   33 FCCN(#) = JCON(K)
                                                                            C0441200
                                                                            CO441300
      FCCN(MI) = K
      GL(1.L) COMPUTED FHOM GF(1.M) AND GF(1.M1)
                                                                            C0441400
         LCON(L) = - P HELPS LCGIC IN SUBROUTINE THANVO
                                                                            C0441500
      LCCN(L) = -M
                                                                            C0441600
   34 FRINT cet. OF(1.M). OF(1.M1)
                                                                            C0441700
                                                                            00441800
      FRINT 225. M.OF(2.F).M1.CF(2.M1)
      IF (K.EG.1) GO TO 35
                                                                            00441900
```

```
PRINT 23C. FCCN(#).QF(3.#).FCUN(#1).QF(3.#1)
                                                                             CC442000
                                                                            C0442100
      GO TC 36
   35 FRINT 223.
                         GF(3.M).FCON(M1).GF(3.M1)
                                                                             C0442200
                                                                             C0442300
   36 CONTINUE
                                                                           . 00442400
      PRINT 231. L
      IF(IASIEN .EU. 0 ) PRINT 224
IF(IASIEN .EG. 1 ) PRINT 243
                                                                            C0442500
                                                                             C0442600
      FRINT 225. (I.THA(I).I.THAC(I).I=M.MI)
                                                                             C0442700
      FRINT 226
                                                                             00442800
      CC TC 1
                                                                            C0442900
                                                                             CC44 3000
C
      FCCN(K) = 2 GNE DEGREE OF FREEDOM
                                                                             C0443100
   15 READ 102. (GF(J.M).J=1.3)
                                                                            C0443200
                                                                             CC4433CO
      HEAD 102. (QL(J.L).J=1.3)
                                                                            C0443400
      READ 102. THA(M)
      READ 132. THAD (M)
                                                                            C0443500
                                                                            C0443600
      FRINT 232. KI
      IF (RELUCK)) GU TO 37
                                                                             (0443700
                                                                            C0443800
      FCCN(N) = K
                                                                            C0443900
      LCCN(L) = K
      LCCN(LI) = K
                                                                            C0444000
                                                                            C0444100
      GU TC 38
   37 FCCN(F) = JCCN(K)
                                                                            C0444200
      LCCN(L) = K
                                                                            C0444300
      LCCN(LI) =
                  K
                                                                            C0444400
                                                                            C0444500
   36 PRINT 223. OF(1.M)
      PRINT 234. M. GF (2.M)
                                                                            C0444600
                                                                            C0444700
      IF (K.EQ. 1) GO TO 39
      PRINT 232, FCGN(M), QF(3.M)
                                                                            CC44480C
      GC TC 40
                                                                            C0444900
   35 FRINT 266. UF (3.M)
                                                                            CC445000
                                                                            C0445100
   4C FRINT 265. UL(1.L)
      FR INT 276. L.OL(2.L)
                                                                            C0445200
                                                                            CC445300
      FRINT 271. LCCN(L).QL(3.L)
      FRINT 231. L1
                                                                            C0445400
      IF (1/51GN .EU. 0 ) PRINT 224
                                                                            C0445500
      IF ( 1 431 GN .EG. 1 ) PRINT 243
                                                                            C0445600
                                                                            CC445700
      FRINT LEE. M. THA(N).N. THAC(M)
      FRINT 226
                                                                            CC445800
                                                                            CC4459C0
      CO TC 1
                                                                            C0446000
C
      FCCN(K) = 3. ZERG CEGREES CF FREEDOM
                                                                            C044610C
                                                                            0946200
   17 READ 132. ((QL(J.1).J=1.3).[=L.L1)
                                                                            C0446300
      FRINT 274. KI
                                                                            C0446400
      LCCN(L) = K
      LCCN(LI) = K
                                                                            C0446500
                                                                            C0446600
      LCCN(L2) = K
      FRINT 23t. QL(1.L). QL(1.L1)
                                                                            C044670C
      PRINT 2:7. L.GL(2.L).L1.GL(2.L1)
                                                                            C0446800
      FRINT 23E. LCON(L).QL(3.L).LCJN(L1).QL(3.L1)
                                                                            CC446900
                                                                            CC44 7000
      PPINT 231. L2
                                                                            CO447100
      FRINT 226
                                                                            CO447200
    I CENTINUE
                                                                            C0447300
C
     READ IN THANSLATICNAL VELUCITY CONDITIONS FOR HINGE POINT ZERC
                                                                            C0447400
C
                                                                            CC44750C
       RELATIVE TO INERTIAL CHIGIN
C
                                                                            CC44 7600
      FEAD 130, PCCN (NBCD+1)
                                                                            C0447700
      NFR = 4+3-PCON(NBCD)
                                                                            C0447800
      NLR = L+FCON(NEOD) - 1
      FRINT 244
                                                                            CC44 7900
```

```
FRINT LEC.PCUN (NBCD+1)
                                                                            CO448000
      13 = 3-P(CN(NBOD+1)
                                                                             C0448100
      IF (13.20.0) GO TO 25
                                                                             C0448200
      COMPLIE INITIAL DISPLACEMENT OF HINGE POINT ZERO FROM CB(1)
C
                                                                             CC44830C
        INFUTING THIS WOULD EE HECUNDANT INFURMATION
C
                                                                            C0448400
                                                                             CC44 8500
C
      CO 16. I=NFR.NFR+13-1
      ITEST=NFF+13-1
                                                                             C0448600
      IF (I 1EST .LT . NF m) GO TO SCCC
                                                                             C0448700
      CO 16 I=NFR. ITEST
                                                                             CC448800
   18 THA(1) = CB(1+1-NFh.1)
                                                                             CC448900
 SOOC CONTINUE
                                                                            CC449000
      READ 132. (THAD(1).I=NFR. ITEST)
                                                                             C0449100
                                                                             C0449200
      FRINT 261
      FRIN1 24:
                                                                             C0449300
      PRINT 225.(1.THA(1).1.THAC(1).1=NFH.1TEST)
                                                                            CC449400
      FRINT 253
                                                                             C0449500
      GO TC 26
                                                                             C0449600
   25 FRINT 248
                                                                             C0449700
                                                                            C0449800
   26 FRINT 264
      CO 22 1=1.3
                                                                             CC449900
      IF(1.01.13) GO TO 23
                                                                            CC450000
      CHA(1) = 0.00+30
                                                                             C2450100
                                                                            CC450200
      GO TC 22
                                                                            C0450300
   23 (BN(1) = Cd(1.1)
                                                                            C0450400
   22 CONTINUE
      FRINT 265
                                                                            C0450500
      FRINT 266
                                                                             C0450600
      FRINT 267
                                                                            C045070C
      NFER = NFR+13-1
                                                                            20450800
      NLOR = NLR+PCON (NECD+1)
                                                                            C0450900
      FRIN1 253
                                                                            C0451000
      FRINT 245. NFER
                                                                            C0451100
      FRINT ZEC.NLUR
                                                                            C2451200
      FRINT 226
                                                                            C0451300
                                                                            CO 451400
C
C
      READ IN MOMENTUM WHEEL DESCRIPTION
                                                                            C0451500
C
                                                                            C0451600
                                                                            C0451700
      READ 133. NMC
      IF (NAC.EG. O) GC TC 50
                                                                            CC 451 80C
      FRINT 235. NMC
                                                                            CC451900
                                                                            C0452000
      CU 16 1=1.NMO
      READ 134. MJ(1).(FM(J.1).J=1.3)
                                                                            CC45210C
      MEAD 136. PLM(1). (MESS(J).J=1.16)
                                                                            CC452200
      SEA) 132. THAN(1) .THADW(1)
                                                                            C04523C0
      FRINT 285. 1.MO(1).(MESS(J).J=1.16)
                                                                            CO452400
      PRINT 274. HM(1.1).MO(1)
                                                                            00452500
      FRINT 275. HM(2.1)
                                                                            C0452600
      PRINT 276. [.HM(3.1)
                                                                            C0452700
      FRINT ZEE. PLM(I)
                                                                            C0452800
      FRINT 28C. I
                                                                            00452900
                                                                            CO453COO
      PRINT 261. I.THAU(1)
      PHINT ZEZ. I.THAD .(1)
                                                                            C0453100
      FMCM(1) = PLM(1) + TFADW(1)
                                                                            00453200
      FRINT 264. HMCM(1)
                                                                            (0453300
      IF ((1/2)+2.EQ. 1) GC TO 15
                                                                            C045340C
      FRINT 253
                                                                            C0453500
      FRINT 252
                                                                            CO45 36CO
      GC TC 16
                                                                            C0453700
   IS PRINT 226
                                                                            CC45 3800
                                                                            02453900
   16 CONTINUE
```

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SC CONTINUE
                                                                          0454000
C
                                                                         C0454100
C
      READ IN INTEGRATION STEP SIZE
                                                                         C0454200
      READ 132. H. TIMEND
                                                                         C0454300
      FRINT 253
                                                                         CC45440C
      FRINT 273. H
                                                                         00454500
      FRINT 253
                                                                         00454600
      PRINT 2ES. TIMEND
                                                                         C0454700
  100 FORMAT (15)
                                                                         CC454800
  101 FORMAT (L5.215.015.5)
                                                                         00454900
  102 FORMAT (3015.5)
                                                                         C0455000
  103 FORMAT (3L5)
                                                                         00455100
  104 FORMAT (15.3015.5)
                                                                         C0455200
  105 FORMAT (15.18A4)
                                                                         (0455300
  106 FORMAT (D15.5.10A4)
                                                                         (0455400
  199 FORMAT( 11.20(/))
  200 FORMAT (22x, 'INPUT DATA FOR ', LJ, ' BUDIES (A CUNSISTANT SET OF UNICO455600
     +15 MIST LE USED) "./)
  201 FORMAT (5x. BODY NUMBER' . 13. (PGINT MASS) . 1844./)
                                                                         C04558C0
  202 FORMAT (5x. GODY NUMBER! . 13. (RIGID GODY) . 1844./)
                                                                         CC455900
  203 FORMAT (10x, 'dody', 13, ' CONNECTED TO BUDY', 13, ' AT HINGE POINT', 1300456000
     1./)
                                                                         CC456100
  234 FUHMAT (10x. *CENTER OF MASS OF BUDY 1 CAN TRANSLATE AND ROTATE IN CO456200
     INTERTIAL SPACE ')
  235 FORMAT (10x. 'MUTICA CONSTRAINED ADOUT', 13. * AXES AT HINCE POINT', 100456400
     *3. ' CF ECDY' . [3./)
                                                                         C0456500
  206 FORMAT (1Cx. 'ICTAL MASS OF ECDY '.12,' ='.D11.D.' (M) './/)
                                                                         CC456600
  207 FORMAT(10x. *CCMPONENTS OF VECTUR FROM . .DID.5.* (BODY . 13.00456700
     . FIXED ')
                                                                         C0456800
  20E FORMAT (10x. ' HINGE POINT'. 13. ' TO CENTER
                                                    .015.5.
                                                                    COORD 0456930
     . INATES) . )
                                                                         00457000
  205 FORMAT (10x. ' CF WASS CF ECCY', 13.11x, D15.5, 10x. '(L)',//)
                                                                         C0457100
  210 FORMAT (10x. COMPENENTS OF VECTOR FROM
                                                 ".D15.5." (INERTIAL CO457200
     . . .
                                                                         C04573C0
  211 FURMAT (1CX. ! INERTIAL CRIGIN TO CENTER
                                                 1.015.5.1
                                                                    CC CRC CO 457400
    *INATES! 1)
                                                                         CO457500
  212 FORMAT (10x. " OF MASS OF BODY 1
                                                 '.D15.5.10x.'(L)'.//) C045760C
  213 FORMAT (10x. COMPENENTS OF VECTUR FROM '.D15.5.' (HUCY'.13.00457700
    * FIXED ')
                                                                         C045780C
                                                    .015.5.
                                                                    CUCRD CO 457900
  214 FORMAT (10x. " HINGE FUINT' . 13. " TO HINGE
    · INATES) ·)
                                                                         CC458000
  215 FORMAT (10x, ' POINT', 13, 21x, D15, 5, 10x, '(L)', //)
                                                                         C04581C0
  216 FURMAT (26x, 3012.5. | BCDY'.13, COCHDINATES ')
                                                                         CC458200
  217 FORMAT (1)x. 'INERTIA TENSOR = '. JD12.5.' UNITS ')
                                                                         CO 45830C
 218 FORMAT (26x, 3012.5,5x, '(**L**2) './/)
                                                                         CC458400
 219 FORMAT (10x. 'THAN SECHMATICN MATRIX '.JOI2.5.5x. DEFINES NUMINAL RC0458500
    IELATIVE ')
                                                                         CC458600
                    BCCY'.13.' TC
  220 FORMAT (10x. *
                                            = '. 3012.5.12x. 'ORIENTATION' ) CO458700
  221 FORMAT (10x. "
                                         1.3012.5.7x. UF BUDY FIXED AXECC458800
                     INERTIAL
 228 FORMAT (10x, ' BCDY', 13, 13x, 3012, 5, 7x, 'UF EGDY FIXED AXES', //)
                                                                         00459000
  223 FORMAT (12x, 'INERTIALLY',9x,012.5.6x,' IN BODY', 13,10x,012.5,//)
                                                                        00459100
 224 FORMAT (10x. INITIAL CUNCITIONS ABOUT FREE AXES (RAD. RAC/SEC0459200
    .(11./1
                                                                         00459300
  225 FORMAT (15x. 'THA( '.12.') = '.012.5.'
                                            THAD (1.12.1) =1.012.51
                                                                         C045940C
 226 FORMAT ( 111)
                                                                         00459500
 227 FORMAT (10x, ' TWO DEGREES OF FREEDOM AT HINGE POINT '.13./)
                                                                         C0459600
 226 FORMAT (10x. *CCMPCNENTS OF FREE *,012.5,6x. *COMPONENTS OF FREE 00459700
     . ..012.51
                                                                         C0459800
 229 FORMAT (10x. * VECTOR*, IJ. * FIXED = *, D12.5.6x. * VECTOR*, I3. * FIXE0459900
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* EC
          = 1.012.51
                                                                          00460000
23C FORMAT (10x.' IN ECDY'.13.10x.012.5.0x.' IN BODY'.13.10x.012.5.//) C0460100
231 FORMAT (10x, 'COMPONENTS OF LOCKED VECTUR'.13,' DEFINED INTERNALLY (0460200
   *EY VECTOR CHOSS PRODUCT 1.//)
232 FORMAT (10x, 'ONE DEGREE OF FREEDOM AT HINGE PUINT', 13./)
                                                                          C0460400
233 FORMAT (10x. COMPENENTS OF FRIE
                                        .012.51
                                                                          C0460500
234 FORMAT (10x. ' VECTOR'. Id. ' FIXED
                                          = ' .D12.5)
                                                                          C0460600
235 FURMAT (10x.' IN EDDY'.13.10x.012.5.//)
                                                                          C0460700
236 FORMAT (10x, 'COMPENENTS OF LOCKED ',D12,5,6x, 'COMPONENTS OF LOCKED 0460800
   · .D12.5)
                                                                          CC46090C
237 FORMAT (10x. ' VECTOR'. IB. ' FIXED
                                          ='.D12.5.0X.' VECTOF'.13.' FIXCO46100C
          =1,012.5)
   *ED
                                                                          00461100
23E FORMAT (10x, ' IN ELDY', 13,10x, 012.5, 6x, ' IN HOUY', 13,10x, 012.5, //) CO461200
239 FORMAT (20x.13." MCMENTLM WHEELS IN SYSTEM".//)
                                                                          C0461300
240 FORMAT (10x, 'MOMENTUM WHEEL '.IJ.' EMECUDED '.D12.5, '
                                                                  UNITS : ) CC 461 400
241 FORMAT (10x. ' IN ECDY' . 13. ' . CUMPONENTS
                                                  = '.012.5.'
                                                                  L*F*T')CC461500
242 FORMAT (10x. FIXED IN ECCY . 13.
                                                    1.012.5.//)
243 FORMAT (10x.
                        INITIAL CONDITIONS ALONG FREE AXES (L.L/T)
                                                                          C0461700
   * 1./)
                                                                          C0461800
244 FURMAT (10x, * TRANSLATICNAL CUNDITIONS ON CENTER OF MASS OF BODY 100461900
   * RELATIVE TO INERTIAL CRIGIN ')
                                                                          00059622
245 FORMAT (10x,5x,13, FREE DIRECTIONS OF TRANSLATION, PARALLEL TO 1, J CO 462100
   .. K INERTIAL AXES RESP !.//)
                                                                          C0462200
246 FURMAT (10x, 'THREE DEGREES OF FREEDOM AT HINGE POINT', 13,/)
                                                                          C0462300
247 FORMAT (* INPUT ERROR IN CATA CARDS: BODIES OUT OF SEQUENCE OR CACO462400
   *FDS MISSING FROM PRECEEDING BUDY CARDS 1)
248 FORMAT (10x, * TRANSLATIONAL MOTION OF BODY 1 C.M. CONSTRAINED ALONGO 462600
   *C ALL THREE INERTIALLY FIXED AXES 1.771
245 FORMAT (10x, ' ENTIFE SYSTEM HAS', IJ, ' UNCONSTRAINED DEGREES OF FRECO462800
   'EDCM './/)
                                                                          C0462900
250 FORMAT (10x. ' ENTIFE SYSTEM HAS .. 13. LUCKED OR CONSTRAINED DEGREECC463000
   *S CF FREEDOM 1.//)
                                                                          C0463100
251 FCRMAT (10x. * DISPLACEMENT ABOUT OR ALUNG FREE VECTOR *.12. * CCMPUCO463200
   *TEC .)
                                                                          C0463300
252 FORMAT (10x, 1 CONSTRAINT TORQUE ABOUT OR ALONG LUCKED VECTOR 1.12 CO463400
   + . * COMPUTED *)
                                                                          C0463500
253 FORMAT (2(/))
                                                                          C04636C0
254 FORMAT (25x, '(GUANTITY)',6x, '(ENGLISH)',9x,' (S1)',9x, '(SYMECL)')00463700
255 FORMAT (25x, ' LENGTH '.6x, ' FUUT '.8x, ' METER '.10x. 'L')
                                                                        C0463800
256 FORMAT (25X. FUNCE
                            '.6x.' POUND '.8x.' NEWTUN '.10x.'F')
'.6x.' SECOND '.8x.' SECOND '.10x.'T')
                                                                          00463900
257 FORMAT (25x. TIME
                                                                          C0464200
                            '.6x.' SLUG '.dx.' KILUGRAM'.10x.'M') C046410C
'.6x.' RADIAN '.dx,' RADIAN '.10x.'R'.//)C0464200
25E FORMAT (25x. " MASS
259 FORMAT (25x. ANGLE
260 FORMAT (20x. '(MUTICN CONSTRAINED ALONG '. 13. ' AXEST'. //)
                                                                          C0464300
261 FORMAT (15x, FREE VECTORS ALIGNED WITH INERTIALLY FIXED AXES RESPECC464400
   1CT [VELY 1.///)
                                                                          C046450C
262 FORMAT ( 10x."
                     (TRANSLATIONAL CUNCITIONS GIVEN AFTER BODY . 13. CO464600
   *[ATA11.//)
                                                                          C0464790
263 FORMAT (10x. + COMPONENTS OF FREE VECTUR + . IS. + DEFINED INTERNALL + BC0464800
   .Y VECTOR CRUSS PRODUCT ../)
                                                                          C0464900
264 FORMAT (10x, 'INITIAL CONCITIONS OF ALL DIRECTION COSINE THANSFORMACO465000
   .TICN MATRICES COMPLTED !)
                                                                          00465100
265 FORMAT (12x, 'INTERNALLY FROM THE TRANSFORMATION MATRICES WHICH DEFC0465200
   . INE PUMINAL HELATIVE!
                                                                          C0465300
266 FORMAT (12x, ORIENTATION (2ERO INTERNAL STRESS STATE) AND INITIAL CO465400
   . CONDITIONS FOF !)
                                                                          C0465500
267 FORMAT (12x, 'RUTATION ABOUT THE SPECIFIED FREE VECTORS')
                                                                          C04656CC
266 FURMAT (11x, 'INERTIALLY' .10x .012 .5 .//)
                                                                          C04657C0
269 FORMAT (10x. 'CCMPCNENTS OF LOCKED '.012.5)
                                                                         C0465800
27C FORMAT (10x. ' VECTOR'. 13. FIXED
                                         = 1.012.51
                                                                         CC4659C0
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271 FORMAT (10x. ' IN BCDY' . 13.1CX . D12.5.//)
                                                                        CC46600C
272 FORMAT (10x, 'ZERO CEGREES OF FREEDOM AT HINGE POINT', 13./)
                                                                        C0466100
273 FORMAT (10x. 'INTEGRATION STEP SIZE FUR FIXED STEP RUNGE KUTTA INTECC466200
   *GRATICA (FOURTH ORCER) = .. 012.5)
                                                                        C0466300
274 FURMAT (15x, 'COMPONENTS OF UNIT VECTUR '.D12.5.' (BODY'.13.' FIXCO4664CO
  *ED .)
                                                                        C04665C0
275 FORMAT (13X. ALCNG SFIN AXIS UF
                                            = 1.012.5.1 CGORDINATES ) C04666CO
  . . )
                                                                        00466700
276 FORMAT (15x. 1
                    WHEEL'. 13.16X.012.5.//)
                                                                        CC4668CO
28C FORMAT (25x. ' INITIAL CUMDITIONS FOR WHEEL', 13./)
                                                                        C046690C
281 FORMAT (30x, 'THAM(',12.') = ',012.5,' RAD')
                                                                        CC467000
262 FORMAT (29x, 'THAD &(',12,') = ',D12.5.' HAD/SEC './)
                                                                        C0467100
264 FORMAT (10A. "ANGULAR MCWENTUM ABOUT SPIN AXIS = ",D12.5," M*L**2/SEC0467200
   *: 1./1
                                                                        C0467300
2d5 FORMAT (10%, "MCMENTUM WHEEL", 13, " EMBEDDED IN BUDY", 13, 5%, 16A4, //) C0467400
236 FORMAT (10x. "HOTATIONAL INERTIA AUGUT SPIN AXIS
                                                        '.D12.5.' W+L CC467500
   ***2 1.//)
                                                                        CC467600
286 FORMAT (10x, 'RIGIC BUDY OR GYRJSTAT NUMBER' . 13)
                                                                        C0467700
289 FORMAT(1CX. PROGRAM TIME TERMINATOR= .D12.5)
                                                                        C0467800
    SE TUEN
                                                                        C0467900
    ENC
                                                                        CC468000
```

```
C
                                                                      0500000
      SUBRICUTINE INERUR
                                                                      CO 5 201 00
C
                                                                      (0500200
C
                                                                      C0500300
C
       INERGH PERFORMS VARIOUS CHECKS ON INPUT DATA TO CHECK
                                                                      C0500400
C
        FOR EASIC TYPING ERRORS IN INPUT DATA AND VIOLATIONS
                                                                      CCECOSCO
        OF BASIC FUHMALISM RULES
C
                                                                      00500600
C
                                                                      00500700
C
                 THE DEFINED SYSTEM MUST BE PHYSICALLY HEALIZABLE
                                                                      00500800
C
                                                                      CC500900
                                                                      CC5210C0
      IMPLICIT REAL+8(A-F.G-Z.4)
                                                                      (0501100
     LUGICAL FOI. FG2. FG3. FG4. F iS. INCHF. HOLC. LEGU. LINIT(1)
                                                                      C050120C
      LCCICAL
                     ASTART. LHTAPE
                                                                      C0501300
C
                                                                      CC5C1400
C
                                                                      CO501500
     INTECER
                                                                      C05016C0
                  . CT2 . CT3 . CT4 . CT5 . FCCN . PCON . C0501700
     . ANDRK . CTI
     * SCNEUM. SCN . SCRDUM. SCR . SFKDJM. SFK . SFH . SG
                                                                  . 00501800
                    . SIXDUM. SIX
                                   . SKOUN . SK
                                                   · SL
     * S1
            . 510
                                                          . SLK
                                                                      C05C1900
                                    . SCA . SPIDUM. SPI . SUF
                                                                   . ((502000
     . SVA
            . SMCDUM, SMC . SMV
                                          . SVB . SVD . SVI . C05021C0
     * SCL
            . SH
                   . SSCN . SSIX . SVA
           . SVP
                                   . SXT . TORU . SMAL . SEU . SFXM . NMCDS . SFCC . SCC
                                    . SXT
                   . SVQ . SXM
                                                                     C050220C
     * SVM
                   . NFL XH . SFL X
     * SC
            . 500
                                                                     00502300
     · IINIT(1)
                    . IZINIT(1)
                                    . SC
                                                                      C0522400
C
                                                                      0502500
                                                                      CC5026C0
C
     FE AL + 8
                                                                      C0 5027C0
     * ANGC (33) , CNF (3.10) , ETIC (3.10) , ETMC (3.10) , C0502800
     • FLO (3.20) . FLE (3.3.20). FLH (3.3.20).
                                                                      C05C29C0
                                                  . RZINIT(1)
     * THACO (33) , YMCD (3,2,11), RINIT (1)
                                                                      CC503000
C
                                                                      C0503100
C
                                                                      C0503200
                                                                      00503300
```

```
CCHMCN /CHEKS/
                                MSTART. LATAPE
                                                                           CO 503400
C
                                                                           C0503500
C
                                                                           C0503600
     COMMEN /LUGIC/ FG1. FG2. FG3. FG4. FG5. INEMF. RBLO(10)
                                                                           C05C3700
c
                                                                           C0503800
                                                                           C0 5 0 3 9 0 0
C
     COMMEN /INTG/
                       ANDRK (200)
                                                                           C0504C00
                                      . CT3
                                                      . CT4
                     . C12
                                                                           CO 504100
     • CT1
     * CT5
                     . FCON
                              (33)
                                      . JCCN
                                              (10)
                                                      . LCCN
                                                              (22)
                                                                           C0 5042 C0
                     . NE1
                                      . NBUD
                                                      . NCTC
     . ..
                                                                           C05043C0
             (10)
     . NFER
                     . NEKC
                                      . NFRC
                                                       . NLUR
                                                                           C05044C0
                     . MMO
                                      . NMOA
                                                       . NSVP
                                                                           C0 504500
     . NHV
                                                      . SFR
                                                               (33)
     . NEVC
                     . FCGN
                             (11)
                                      . 50
                                                                           C0504600
     . 56
                     . 51
                              (55)
                                      . SIG
                                                      . SL
                                                                           C05047C0
                                                      . SUF
                     . SMA
     . SLK
             (23)
                              (10)
                                      . SCK
                                              (11)
                                                               (11)
                                                                           C05048C0
                                                                       ٠
                     . SHV
                                      . SH
                                                      . SSCN
     . SCL
             (11)
                                                                           C05C4900
                                      . SVB
                                                      . SVC
                     . SVA
     . SS1 x
                                                                           C0505000
                                      . SVP
                                                      . SVC
     * SVI
                     . SVM
                                               (22)
                                                               (33)
                                                                           C0505100
             (3.10)
                     . SXT
                                      . TOFG (97)
                                                      . SMAL
     * SXM
                                                                           C0525200
                                              (33)
                                                      . SCG
     * SEU
                     . NTO
                                      . 50
                                                                           C0505300
                     . SFLX
                                      . SFXM (10)
                                                       . NMODS
     * NFL >3
                                                                           C0525400
     . SFCC
                     · SCC
                              (10)
                                                                           C05055C0
C
                                                                           C0505600
C
                                                                           C0505700
     CCHMEN /INTOZ/
                                                                           C0505800
                                                      . SCR
     . SCNDLA
                     . SCN
                              (5)
                                      . SCROUM
                                                               (9)
                                                                           C0505900
                     . SFK
     . SFKCUM
                              (5)
                                      . SIXDUM
                                                      . SIX
                                                               (9)
                                                                           C050600C
                     . SK
     * SKELN
                              (5)
                                      . SPIDUM
                                                      . SPI
                                                               (9)
                                                                           C0506100
     . SHCELM
                     . SMC
                              (5)
                                                                           0506200
                                                                           CO 5 26 300
C
                                                                           C0506400
     COMMEN /FEAL/
                                                                           C0506500
     . ..
            (3.10) . CAC
                                             (10)
                                                      . CCMC (3.11) . C0506600
                              (3.10) . CLM
     * DCMC (3.11) . ETC
                              (3.11) . ETM
                                              (13)
                                                      . FCML (3.11) .
                                                                           CC50670C
                                                               (2.10) .
     * GAM
             (2,66) · F
                                      . HM
                                              (3.10) . HMC
                                                                          C05068CC
                                                      . OF
     . HMC .
             (10)
                     . PHI
                              (2.11)
                                      . PLM
                                              (10)
                                                               (3.33)
                                                                           C0506900
                    GL
                                                               (2.11) .
     . QFC
                              (3,22) . ULC
                                                     . RGMC
             (2,33)
                                              (3,22)
                                                                          CC507000
                                                      . THAD
     * T
                                        THA
                                              (33)
                                                              (33)
                                                                          C0507100
                  . THAW
     * THACH (10)
                             (10)
                                      . XDIC
                                              (3.3.60). XI
                                                               (3.3.10).
                                                                           C0507200
                              (10) . XMN
(3.20) . FLB
     * XIC
            (3.3.10) . XMAS
                             (12)
                                              (33,33) . XMT
                                                               (3.3.10) .
                                                                           C05C7300
     * TLG
             (33) . FLA
                                              (J.20) . FLC
                                                               (3.20) .
                                                                           CC537400
                                              (3.10) . XIU
     . FLD
            (3.3.20). FLJ
                             (3.3.20). CAC
                                                               (3.3.10).
                                                                           C0507500
     * FLIRC (3.10) . FLCRC (3.10) . FLAC (3.20) . FLQC (3.20) . 
* FLCN (20) . ZETA (20) . FCF (3.3.40). FCK (3.40) .
                                                                           C0507600
                    . ZETA (20)
                                                                           C05077C0
     & TIMENO
                                                                           C0507800
C
                                                                           CCE C7900
                                                                           00060300
     CCHMEN /FEALZ/
                                                                           C0508100
                                                               (3.10) .
     . CEDLM (1.3) . CE
                              (3.10) , CHCDUM(1.3) , CBC
                                                                           C0508200
     * XMCCL4(1.1.5) . XMC
                             (3.3.10), CON(J)
                                                                          C0508300
C
                                                                          C0508400
                                                                           (0508500
     EQUIVALENCE (ETM(1).THADC(1))
                                             . (XMN(1.1). ANGD(1))
                                                                          CC5C8600
                  (XMN(1.3).YMCD(1.1.1))
                                             . (XMN(1.6).CNF(1.1))
                                                                          C0508700
                  (XMN(1.6).ETIC(1.1))
                                             .(XMN(1.10).ETMC(1.1)) .
                                                                          00608600
                  (FLB(1.1).FLG(1.1))
                                             .(FLE(1.1.1).FLD(1.1.1)).
                                                                           C05089C0
                  (FLH(1.1.1).FLJ(1.1.1))
                                                                          CC5090C0
                  (FG1.LINIT(1))
                                             .(CA(1.1).RINIT(1))
                                                                          C0539100
                 (CHDUM(1.1).FZINIT(1))
                                             . (AWORK(1). 11NIT(1))
                                                                         C0 = 09200
                  (SCNDUM. IZINIT(1))
                                                                          CC529300
```

```
C
                                                                            CO = C94C0
C
                                                                            C0509500
C
                                                                           CC509600
C
                                                                           C0509700
      CIMENSICK GO (3)
                                                                           CC509800
C
                                                                           C0509900
C
                                                                           CC510000
      h = 1
                                                                           CC510100
      L = 1
                                                                           00510200
      CYCLE THAU DATA FOR ALL ECDIES
C
                                                                           CO510300
      CO 1 K=1.NBCD
                                                                           CO510400
C
      CHECK TO SEE IF BODY MASS IS PUSITIVE
                                                                           CC5105C0
      IF (XMAS(K).GT.O) GC TO 1C
                                                                           C0510600
      FRINT 2CC. K.XMAS(K)
                                                                           CO510700
      FG2 = .FALSE .
                                                                           C05108CC
      CHECK TO SEE IF TOFOLOGICAL TREE PROPERLY LABELED
C
                                                                           C0510900
   IC IF (JCCN(K).LT.K) GO TO 11
                                                                           CC511000
      FRINT 201. JCCN(K).K
                                                                           CO5111CO
      FG2 = .FALSE .
                                                                           00511200
      CHECK NUMBER OF CONSTRAINED AXES. AT MOST 3
C
                                                                           CO5113CO
   11 IF (PCON(K).GE.C.ANC.PCCN(K).LE.3) GC TU 12
                                                                           CO511400
      K1 = K-1
                                                                           C0511500
      FRINT 202. K.PCON(K).K1
                                                                           CC5116C0
      FG2 = .FALSE .
                                                                           C0511700
   12 IF (.NGT.FBLU(K)) GL TO 13
                                                                           CO511800
      CO 2 1=1.3
                                                                           C05119C0
      CO 2 J=1.3
                                                                           C0512000
      CHECK SYMMETRY OF INERTIA TENSOR
                                                                           CO512100
      IF (XI(1.J.K).EG.XI(J.I.K)) 6C TU 2
                                                                           CO512200
      FRINT 203. K
                                                                           CO5123CO
     FGE = .FALSE .
                                                                           C0512400
    2 CONTINUE
                                                                           C0512500
      CETERMINANT OF INERTIA TENSOR MUST BE POSITIVE FOR IT
C
                                                                           (0512600
       TO HAVE REAL PRINCIPAL MCMENTS OF INERTIA
                                                                           CC512700
     CET = x1(1,1,K)*(x1(2,2,K)*x1(3,3,K) - x1(2,3,K)*x1(3,2,K))
                                                                           00512800
          -X1(1,2,K)*(X1(2,1,K)*X1(3,3,K) - X1(3,1,K)*X1(2,3,K))
                                                                           CC512930
           +x1(1,3,K)*(x1(2,1,K)*x1(3,2,K) - x1(2,2,K)*x1(3,1,K))
                                                                           CO513000
     IF (DET. C1.0) GO TO 13
                                                                           CO 51 41 00
      FRINT 204. K.DET
                                                                           CO513200
      FG2 = .FALSE .
                                                                           CO 51 3300
      CHECK CRINGGENALITY OF TRANSFURMATION MATRIX
                                                                           CO513400
   13 00 3 1=1.3
                                                                           CO 51 3500
      CO 3 J=1.3
                                                                           CO513600
      TEST = C
                                                                           CO513700
      CO 4 L=1.3
                                                                           CO513800
    4 TEST = TEST + XMT(L.I.K) *XMT(L.J.K)
                                                                           CO 51 3900
      IF (1.EG.J) GC TO 14
                                                                           CO514000
      IF (DAES(TEST).LT.. ID-03) GC TO 3
                                                                           C05141C0
      FRINT 205. I.J.TEST.K
                                                                           CC514200
                                                                           CO5143CC
      FG2 = .FALSE .
     CO TC 3
                                                                           CO514400
  14 IF (CAGS(DABS(TEST)-1.DC).LT..13-03) GO TO 3
                                                                           CO 514500
      PRINT 205. 1.J. TEST.K
                                                                           00514600
      FG2 = .FALSE .
                                                                           CO5147CO
                                                                           CC514800
   3 CONTINUE
    I CONTINUE
  200 FURMAT (10X, MASS OF BODY 13, 1 = 1,015.5, 2ERO OR NEGATIVE MASS EC0515000
    *LEMENTS UNACCEPTABLE 1./)
                                                                           C0515100
  201 FORMAT (10x, 'JCON(K) MUST BE LESS THAN K BODY', 13, ' CANNUT LIE BETCOE15200
    *WEEN BODY I AND BEDY . IS. IN TUPOLOGICAL TREE . //
                                                                           CO 51 5300
```

```
C
                                                                            C06200C0
      SUBFICUTINE SETS
                                                                            CO 600100
C
                                                                            C0600200
                                                                            C0600300
C
      IMPLICIT REAL+8(A-h,0-2,1)
                                                                            C0600400
      LOGICAL FG1. FG2. FG3. FG4. FG5. INERF. RBLC. LEQU. LINIT(1)
                                                                            CO£00500
      LCCICAL
                        NETART. LATAPE
                                                                            C0 60 C60 C
C
                                                                            C062C700
                                                                            CO€00800
      INTECER $1(10).52(10).5244#1
                                                                            C06C0900
      INTECEN
                                                                            C0601000
                      . CT2
                              . CT3
                                                       . FCON
                                                                . PCCN
     . ANDRK . CTI
                                      . CT4 . CT5
                                                                            COE01100
                                                                        .
                     . SCROUM. SCR
                                      . SFRCUM. SFK
     . SCNEUP . SCH
                                                       . SFR
                                                                . SG
                                                                            0051200
                                                                         .
                                       . SKDUM . SK
                                                                . SLK
     • SI
             . SIG
                      . SIXDUP. SIX
                                                       . SL
                                                                            C0601300
                                       . SOK
                                               . SPIDUM, SPI
     * SNA
             . SMCDUM, SMC . SMV
                                                                . SQF
                                                                            CO601400
     . SCL
             . SR
                      . SSCN
                              . SEIX
                                      . SVA
                                               . SVE . SVD
                                                                . SVI
                                                                            CO € 01 500
                              . SXP
                                       . SXT
             . SVP
                      . SVQ
                                                                . SEU
                                               . TORU . SMAL
     . SVM
                                                                            CO 601600
                                                                         .
     . 50
             . SCG
                     . NFLX9 . SFLX
                                      . SFXM . NMODS . SFCC
                                                                . SCC
                                                                            CO € C1 700
                     . IZINIT(1)
                                      . 50
     . IINIT(1)
                                                                            COMPINAC
C
                                                                            CO601900
C
                                                                            C0602000
      REAL .
                                                                            C0602100
                      . CNF
     * ANGC (33)
                              (3.10) . ETIC (3.10) . ETMC (3.10) .
                                                                            C0602200
     * FLO
             (2.20)
                     . FLE
                              (3.3.23). FLH
                                               (4.3.20).
                                                                            CO € 0230C
                      . YMCD (3.2.11), RINIT (1)
     (LE) COAHT #
                                                       . RZINIT(1)
                                                                            C0602400
C
                                                                            CO € 0250C
C
                                                                            CD € 2260C
C
                                                                            C0602700
     COMMEN /CHEKS/
                                NSTART. LRTAPE
                                                                            C0602800
C
                                                                            CC602900
C
                                                                            CC603000
      CCMMCN /LUGIC/ FG1, FG2, FG3, FG4, FG5, INERF, RBLU(10)
                                                                            C0603100
C
                                                                            CO € 23200
C
                                                                            CO € 0 3 3 0 0
     COMMEN /INTG/
                        ABORK (200)
                                                                            CO 603400
     · C11
                      . CT2
                                       · CT3
                                                       . CT4
                                                                            CO 60 3500
                      . FCGN (33)
     · C15
                                      . JCCN
                                               (10)
                                                       . LCON
                                                                (22)
                                                                            C0603600
     . MC
             (10)
                                       . NEUD
                                                       . NCTC
                                                                            CO 603700
                      . NE1
     . NFER
                      . NFKC
                                       . NFRC
                                                       . NLOR
                                                                            CO € 0 3 8 0 0
     . ...
                      . MMC
                                       . NHUA
                                                       . NSVP
                                                                            CO603900
     . NSVC
                      . FCON
                              (11)
                                       . 50
                                                       . SFR
                                                                (33)
                                                                            CO60400C
                      . 51
                                       . SIG
                                                                            CC604100
     . 56
                              (55)
                                                       . SL
                                                       . SOF
     . SLK
             (33)
                      . SPA
                              (10)
                                       . SOK
                                               (11)
                                                                (11)
                                                                            CO694200
                                                       . SSCN
                                       . SR
     . SCL
                                                                            CO € 04 300
             (11)
                      . SHY
     . SSIX
                      . SVA
                                       . SVB
                                                       . SVD
                                                                           COE04400
```

```
. SVI
                                                         . SVQ
                       . SVM
                                        . SVP
                                                 (22)
                                                                   (33)
                                                                               C0604500
                                                         . SMAL
     . SXM
              (3.10) . SXT
                                        . TORG
                                                (97)
                                                                              C0604600
                       . NTQ
                                        . sc
     * SEU
                                                 (33)
                                                         . SCG
                                                                              COEC4700
     . NFL X3
                       . SFLX
                                         . SFXM
                                                 (10)
                                                          . NMODS
                                                                              C06C4800
                       . SCC
     . SFCC
                                (10)
                                                                               COE04900
C
                                                                               CCEDSOOC
C
                                                                               C0€05100
      CCHMEN / INTGZ/
                                                                               C0605200
     . SCNCLM
                       . SCN
                                (5)
                                        . SCROUM
                                                         . SCR
                                                                   (9)
                                                                               C0 605 30C
     . SFKCLM
                       . SFK
                                                         . SIX
                                (5)
                                        . SIXDUM
                                                                  (9)
                                                                              C0625420
                                                         . SPI
     4 SKOLM
                       . SK
                                (5)
                                        . SPIDUM
                                                                   (9)
                                                                           . CC605500
     . SPCCUM
                       . SMC
                                (5)
                                                                               CO € 05600
                                                                               C0605700
                                                                               CC605800
      COMMEN /REAL/
                                                                               CO € 05900
             (3,10) . CAC
(3,11) . ETC
(3,66) . H
(10) . FHI
     . .
                                (3.10) . CLM
                                                (10) . CCMC (3.11) . CDEDEOCO
                                                         . FCMC (3.11) .
                                                (33)
     . DCMC
                                (3.11) . ETM
                                                                              CC606100
                                                                   (3.10) .
                                        · HM
     . GAM
                                                 (3.10) . HMC
                                                                               CCE06200
                                                         . QF
     . HACA
                                        . PLM
                                (2.11)
                                                 (10)
                                                                               C0606300
     · OFC
              (3.33) . QL
                                (3.22) . ULC
                                                 (3.22) . ROMC
                                                                 (3.11) .
                                                                              C0606400
                                                        . THAD
                                                                  (33)
     * T
                                          THA
                                                                              C0606500
                                                 (22)
                                        . XDIC
     4 THAC# (10)
                    . THAW
                                (10)
                                                (J.3.66). XI
                                                                   (3.3.10).
                                                                              C0606600
                                                                   (3.3.1C). CCe96700
              (3.3.10). MAS (10)
     * XIC
                                                 (33,33) . XMT
                                        . XMN
     * TLG (33) , FLA (3,20) , FLB (3,10) , XIU (3,3,10), 

* FLD (3,3,20), FLJ (3,3,20), CAU (3,10) , XIU (3,3,10), 

* FLIRC (3,10) , FLCRC (3,10) , FLAC (3,20) , FLUC (3,20) , 

* FLIRC (3,10) , FCF (3,3,40), FCK (3,40) ,
                                (3.2C) . FLB
                                                                              CC606800
                                                                  (3.3.10).
                                                                              CC606900
                                                                               CCEC7CCC
                                                                               CO+C710C
     . TIMEND
                                                                               COE07200
C
                                                                               COE07300
C
                                                                               CO607400
     COMMEN /HEAL Z/
                                                                               CC60750C
     • CEDLM (1.3) . CE
                               (3.10) . CBCDUM(1.3) . CBC
                                                                  (3.10) . CO607600
     * XMCCLM(1.1.9) . XMC
                              (3.3.10), CUN(3)
                                                                               C0607700
                                                                               €0€0780€
C
C
                                                                               CC607900
      EQUIVALENCE (ETM(1).THACC(1))
                                               .(XMN(1.1), ANGD(1))
                                                                              COEDBOOC
                    (XMN(1.3).YMCD(1.1.1))
                                                . (XMN(1.6), CNF(1.1))
                                                                              COE28100
                    (XMN(1.8).ETIC(1.1))
                                                .(XMN(1.10).ETMC(1.1)) .
                                                                              COEC8200
                    (FL8(1.1).FLG(1.1))
                                                . (FLE(1.1.1).FLD(1.1.1)).
                                                                               CO 608300
                    (FLH(1.1.1),FLJ(1.1.1))
                                                                              COECHADO
                    (FGI.LINIT(1))
                                                .(CA(1.1).RINIT(1))
                                                                              CC60H5CC
                                               . (A@OHK(1).11NIT(1))
                   (CBDUM(1.1).62[NIT(1))
                                                                              00480900
                    (SCNDLM. IZINIT(1))
                                                                               CCECHTOC
C
                                                                               CC6C8800
C
                                                                               COEC8900
                                                                              CC609000
C
                                                                               C0609100
C
                                                                              CC € 29200
C
C
                                                                              C0639300
C
     CET THE SETS SE AND SL
                                                                              CO609400
       SR = SET OF BODY LABELS OF RIGID BUDIES (COMPACTED)
C
                                                                              C0629500
C
        SL = SET OF BODY LABELS OF LINEAR OSCILLATORS (COMPACTED)
                                                                              CCC0960C
       SG = SET UF BUDY LABELS CF GYROSTATS (CLMFACTED)
C
                                                                              CCE09700
C
                                                                              00609800
                                                                              CCEC9900
C
      NR = 0
                                                                              COE1000C
      NL = 0
                                                                              COE10100
      CO 1 1=1.NB00
                                                                              CO610200
      IF (RELU(I)) GO TO 14
                                                                              CC610300
      NL = NL + 1
                                                                              C0610400
```

6

```
COC1050C
       52(NL) = I
       CU TC I
                                                                            C0e10600
   14 NR = NH + 1
                                                                            CCE1 0700
       S1 (NE) = 1
                                                                            CC61 080C
     1 CCATINUE
                                                                            C0 €1 C900
                                                                            CC611000
       COMPACT SI (NR) INTO SR AND
C
C
               SZ(NL) INTO SL
                                                                            C0611100
                                                                            CO#11200
       (ALL CLAFAC(SI.NR.SR)
       CALL CUMFAC(S2.NL.SL)
                                                                            C0611300
C
                                                                            CO£11400
       CET SET SG OF GYROSTAT ECDY LAUELS
                                                                            CO411500
       IF (NAG. EC. 0) GO TC 19
                                                                            CO 61 160C
       CO 1e 1=1.10
                                                                            COE11700
       51(1) = C
                                                                            C0611800
   16 S2(1) = C
                                                                            CO£11900
       DC 17 N=1.NMC
                                                                            CC612000
                                                                            C0612100
       L = MC(N)
    17 SI(L) = 1
                                                                            COE12200
                                                                            C0612300
       K = C
       CO 16 1=1.10
                                                                            COE12400
       IF ($1(1).Lu.0) GU TC 18
                                                                            CO£12500
       # = K+1
                                                                            00612600
       $21K) = 1
                                                                            CO612700
   18 CONTINUE
                                                                            00812800
       (ALL CENFACESZ.K.SG)
                                                                            00612900
                                                                            CCE13000
       GU TC 15
                                                                            CO €13100
   15 EG = C
       60 TC 15
                                                                            CO£13200
C
                                                                            CO£13300
       CET THE SETS OF BODIES OUTBOARD OF HINGE POINT K
                                                                            CO61 340C
C
                                                                            CO61350C
          COMPACTED FORMS IN SKIK)
   15 NM1 = NECD - 1
                                                                            CO613600
                                                                            CO €13700
       00 2 L=1.NBUD
                                                                            COE1 3800
       K = L-1
       CO 4 1=1.NBGD
                                                                            CO €1390C
    4 SI(1) = C
                                                                            CC614000
      AC = C
                                                                            CCELALOC
C
       CYCLE THAU BUDIES WHICH CAN BE OUTBUARD OF K
                                                                            CO 61 4200
       ITEST = K+1
                                                                            COE14300
      CU 3 J=I1EST.NOUD
                                                                            CO61440C
      IN = J
                                                                            CC614500
    5 IF (IN-1-K) 0.7.8
                                                                            COC14600
       ECCY J NCT ON PATH FREN K
                                                                            CC614700
C
    e 60 TC 1
                                                                            CO614800
      ECCY J CLTBUARD OF HINCE K CN CHAIN FROM K
                                                                            CCE14900
    7 NC = NC + 1
                                                                            CCe15200
       51(NC) = J
                                                                            COC15100
                                                                            CC6152CO
       GO TO 5
C
      EUCY J CAN BE ON CHAIN FROM K
                                                                            CO£15300
    E IN = JCCN(IN)
                                                                            CO615400
       GO TC 5
                                                                            CO615500
    3 CUNTINUE
                                                                            CO 615600
      CCMPACT SET SKIKI
                                                                            CO 15700
C
                                                                            CO£15800
      CALL COMPAC(SI.NC.SK(K))
                                                                            CO615900
    2 CONTINUE
       CET SETS OF BUDIES ON PATH FROM HINGE POINT I
                                                                            CC616000
C
        TO C.M. OF BLCY N+1: SI(KTO(NBOD.L.N)
                                                                            CO6161CO
C
       KTC = FUNCTION TO PUT TRIANGULAR ARRAYS IN ONE DIMENSIONAL ARRAY COELEZOO
C
                                                                            CO 616300
      CO 9 L=1.NBUD
       I = L-1
                                                                            COE16400
```

```
(ALL UNPAC(52.NSET.SK(1))
                                                                             CC61650C
      CO 10 N=1.NM1
                                                                             00616600
   1 C SI(KI)(NBOD. I.A)) = C
                                                                             C0616700
      CO 11 NA=1.NSET
                                                                             00801300
      CO 13 K=1.NBOD
                                                                             CC616900
   13 S1(K) = C
                                                                             00€17000
      NC = C
                                                                             CO € 17100
       IN = 32(AN)
                                                                             CC61720C
   12 IF (IN-1.LT.1) GO TC 20
                                                                             C0617300
   . . NC = NC + 1
                                                                             C0617400
      $1 (NC) = IN
                                                                             COE17500
      IN = JCCN(IN)
                                                                             CC61 7600
      GO TC 12
                                                                             00 61 770 O
   2C CONTINUE
                                                                             C0617800
C
                                                                             CC617900
      (ALL CCMPAC(SI.NC.SI(KTO(NBCO.I.S2(NN)-1)))
                                                                             CC61800C
   11 CCATINUE
                                                                             CO618100
    S CCATINLE
                                                                             (0618200
c
                                                                             CO618300
      CUMPLIE REQUIRED SUMMATION SETS
-
                                                                             CC618400
      MM = 1
                                                                             CO618500
      LL = 1
                                                                             CC4186CC
      CO 22 K=1.NB1
                                                                             20618700
      IF (K.EQ.1) GC TO 23
                                                                             CO618800
      MM = MM+3-PCON(K-1)
                                                                             C061 8900
      LL = LL+FCCN(K-1)
                                                                             CC619000
   23 IF (PCUN(K).NE.3) GC TO 24
                                                                             C0619100
      SQF(K) = C
                                                                             CC61920C
      SGL(K) = LL
                                                                             CO61930C
      GO TC 22
                                                                             CO619400
   24 IF (PCCN(K) .NE. 0) GC TO 25
                                                                             CO619500
      SOF(K) = MM
                                                                             C0619600
      SOL(K) = 0
                                                                             C061970C
      60 TC 22
                                                                             CC6198CC
   25 SQF(K) = MM
                                                                             00619900
      SQL(K) = LL
                                                                             CC€20000
   22 CONTINUE
                                                                             00105303
      SETUEN
                                                                             0050500
      ENC
                                                                             00620300
```

```
CC72300C
C
      SUERCUTINE INOPT
                                                                          CC72010C
      ACCEPTS ALL INFORMATION NEEDED TO DEFINE THE COMPUTATIONAL
C
                                                                          00720200
C
         OFTICAS WHICH CAN BE EXECUTED BY THE USER
                                                                          00700300
C
      THE FULLCHING AUGMENTED SET DEFINITIONS ARE MADE
                                                                          CC700400
        'NEST I' = ALL ECDIES CUTECARD OF HINGE POINT I OF BOCY I+1
                                                                          (0700500
C
C
          SPI(I) = ALL ECDIES CF NEST I CONTRIBUTING SIGNIFICANTLY
                                                                          (0722600
C
                   TU PSLEDO INERTIA TENSCRS CF NEST I
                                                                          00700700
C
          SIX(1) = ALL ECDIES OF MEST I CONTRIBUTING SIGNIFICANTLY
                                                                          CC72080C
                   TO INERIA CROSS COUPLING EFFECTS IN NEST I MOTION
                                                                          00700900
C
C
                   EGUATION
                                                                          (0701700
C
          SCN(1) = ALL ECDIES OF NEST I CONTRIBUTING SIGNIFICANTLY
                                                                         00721100
C
                   TO CENTRIPITAL CRUSS COUPLING EFFECTS IN NEST I
                                                                          C0701200
C
                   MUTICA EQUATION
                                                                          C0721300
C
          SCR(I) = ALL ECDIES CF NEST I CONTRIBUTING SIGNIFICANTLY
                                                                         (0701400
                   EULATION
                                                                          (0721500
```

```
TO COFIGLIS CROSS COUPLING EFFECTS IN NEST I MOTION CO701600
        SML(1) = ALL CENSTANT AND VARIABLE SPEED MEMENTUM BREELS
                                                                         C07C17C0
-
C
                   IN NEST I
                                                                         C0701800
             SD = ALL CENTIGUELS PAIRS OF JUDIES (JOUN(K).K) FOR WHICH CO701900
C
C
                   DIRECTION COSINE TECHNIQUES ARE TO BE USED TO COMPLTE CO 702000
                   RELATIVE THANSFORMATION MATRICES
                                                                         (0702100
C
C
                   SO SHOULD CENTAIN JNLY LABELS FOR RIGID OF FLEXIFLE
                                                                        CC702200
C
                   BODIES
                                                                         CC 702 300
           SMAL = ALL CENTIGUELS PAIRS OF BUDIES (JCENK) K) FOF WHICH CO702400
C
                   SMALL ANGLE TECHNIQUES ARE TO BE USED TO COMPUTE
C
                                                                         CO 702500
C
                   RELATIVE TRANSFORMATION MATRICES
                                                                         C0702600
C
            SEU = ALL CENTIGUEUS PAIRS OF BUDIES (JEUN(K).K) FOR WHICH CC702700
                   EULER ANGLE TECHNIQUES ARE TO EE USED TO COMPUTE
                                                                         CC702800
C
                   HELATIVE TRANSFORMATION MATRICES
                                                                         CC702900
       SXP(I.K) = COMPLTED CODE BORD ARRAY
                                                                         CC7C3000
C
                   THE CCORDINATE AXIS IN BODY K ALONG WHICH THE I-TH
C
                                                                         C0703100
                   FREE CH LCCKEC GIMJAL AXIS IS ALIGNED, SIGN IMPLIES CO703200
C
C
                   DIRECTION
                                                                         C0703300
                     'NCTE' INTERNAL LOGIC ASSUMES THAT THE FREE
C
                                                                         CO 703400
C
                     CUCPDINATE VECTURS AT HINGE FOINTS AT WHICH SMALL
                                                                        CO 723500
                     ANGLE OF ELLEF ANGLE TECHNIQUES ARE APPLIED ARE
C
                                                                         CO 70 3600
C
                            PARALLEL TO THE BODY FIXED AXES DEFINED
                                                                         C07C3700
C
                            AT THAT POINT
                                                                         CC 703800
C
           SXT = ALL CCLUMNS OF THE SYSTEM INERTIA MATRIX OF PSUECO-
                                                                        CC7C3900
C
                   INERTIA TENSORS WHICH HAVE TIME VARYING ELEMENTS.
                                                                        C0724200
                   (SINCE INERTIA MATRIX SYMMETRIC COLUMNS DESIGNATED
                                                                        CC704100
C
C
                   EXTEND DOWN CHLY TO DIAGONAL ELEMENT, COLUMN N+1 IS
                                                                        CC7C4200
                   ALBAYS ASSURED TIME VARYING)
                                                                         CC 7C4 3C0
C
C
                   ELEMENTS IN CCLUMN K.K=1.2....N GIVE THE INERTIA
                                                                         CC704400
                   CONTRIBUTIONS OF THE NEST K-1 TO THE SYSTEM EQUATIONSCO794500
C
                   OF MCTION
                                                                         CO 704600
            SMV = ALL VARIABLE SPECD MCMENTUM WHEELS
C
                                                                         CC 7C4 700
C
            SVD = ALL ECDIES IN WHICH BUDY FIXED VECTORS AND DYADS ARE CC704800
C
                   TIME VARYING IN THE COMPUTATIONAL REFERENCE FRAME
                                                                        CC7C4900
        SFA(1) = SET CF FREE COURDINATE VECTOR LABELS OF THOSE VECTORS(0705000
C
                   ABOUT OR ALCNE WHICH DISPLACEMENT IS COMPUTED
                                                                        C0705100
C
         SER(I) = SET OF LOCKED COUNCINATE VECTOR LABELS OF THOSE VECTOCO705200
C
                   AUGUT OH ALENG WHICH CENSTRAINT TORQUE IS CEMPUTED
                                                                        CC705300
                   THIS CAPABILITY NUT AVAILABLE IN N-8002
                                                                        CO705400
C
         SMA(I) = SET OF MOMENTUM WHEEL LABELS OF THUSE WHEELS FOR
C
                                                                        C0705500
C
                   WEICH ANGLLAR EISPLACEMENT IS TO BE COMPUTED
                                                                        C0705600
C
                                                                        C0705700
C
        INCHF = .TRUE. COMPLIATION FRAME IS INCHTIAL REFERENCE
                                                                        C0705800
C
                   .FALSE. CLMFUTATION FRAME FIXED IN BCCY I
                                                                        CC7C5400
C
                                                                         (6706000
         SC(1) = ALL CAGED DEGREES OF FREEDOM
C
                                                                         CC 706100
           SCG = TETAL NUMBER OF CAGED DEGREES OF FREEDOM
                                                                        00236200
C
         TUG(J) = TIME AT WHICH DEGREE OF FREEDON J UNCAGED
                                                                        00706300
                                                                         C0706400
C
                                                                         C0706500
         NFL XD = TCTAL NUMBER OF FLEXIBLE BODIES
                                                                         CO 70660C
C
           SFLX = SET CF ALL FLEXIBLE BOUIES
                                                                         C07C67C0
        SFX4(1) = TOTAL NUMBER OF FLEXIBLE BODY NUDES USED FOR BODY I
                                                                        CC 726890
C
                   (ZERC IF BOCY I RIGID)
                                                                         00706900
          MMCCS = TOTAL NUMBER OF FLEXIBLE BODY MUDES USED FOR ENTIRE
                                                                         CC7C7C00
C
                   SINULATION
                                                                         C0707100
C
                                                                         CO7C7200
c
     RESULTANT FLEXIBLE BODY MCDAL PAR METERS
                                                                         C0707300
C
     FLA(I.MA) = MODE NO CENTER OF MASS
                                                                        CO 70 7400
     FLB(I.MA) = MASS MODAL MEMENT ABOUT HINGE PEINT FOR
                                                                        CO7C7500
```

```
CC7C760C
C
                    MUDE MN DUE TO TRANSLATION OF MASS PUINTS
C
      FLC(I,MN) = INERTIA MCDAL MEMENT FOR MODE WN DUE TO
                                                                       C07C7700
C
                    ACTATION OF MASS PUINTS
                                                                       CC7C7800
    FLD(1.J.MA) = PSUEDC-INERTIA COUPLING TENSOR FOR MODE MN
C
                                                                       C07C7900
C
    FLJ(1.J.MA) = CENTRIPITAL COUPLING TENSOR FOR MODE MN
                                                                       (0708000
C
                                                                       CO 708100
C
              FUR MODE M OF BODY N. MUDAL NUMBER MIN IS
                                                                       C0708200
C
               MN = SFXM(1)+...+SFXM(N-1)+M
                                                                       00708300
C
C
                 FOR ELASTIC COORDINATE MN
                                                                       C0708500
    THAINFER+MN) = INITIAL GENERALIZED DISPLACEMENT, ELASTIC COORD. MN CC7C8600
C
  THAC(NEER+NN) = INITIAL GENERALIZED HATE, ELASTIC COURD. MN
C
                                                                       CC708700
           NFER = TUTAL NUMBER OF FREE COORDINATE VECTORS
                                                                       CO 708800
C
                                                                       CO7C8900
C
           SECC = SET OF ALL FLEXIBLE BODIES FOR WHICH CENTRIPETAL AND CC709000
                   CCRIOLIS EFFECTS SIGNIFICANT IN DEFURNATION EQUATION CO709100
C
C
       SC>C(MN) = SET OF ALL MODES N WHICH SIGNIFICANTLY CONTRIBUTE
                                                                      00709200
C
                   TO THE CENTRIFETAL OR CURIOLIS CROSS COUPLING EFFECTSC0709300
C
                   IN THE EQUATION FUN MODE WITH MUDE NUMBER MN
                                                                      CC709400
C
                                                                       C0709500
C
             RESULTANT MODE CCUPLING COEFFICIENTS FOR MODE M AND N
                                                                       (0709600
       FCF(M.N) = MODE CROSS COUFLING TENSOR CENTRIPETAL ACC. EFFECTS C0709700
C
                   (IN MCST CASES FCF(M.N); MEN CAN HAVE SIGNIFICANT
                                                                       CC709800
C
                  NCN-ZERO TERMS)
                                                                       CC7C9900
C
       FCK(M.N) = MODE CROSS COUPLING VECTOR FCH CORIOLIS ACC. EFFECTS C0710000
C
                                                                       C0710100
C
                                                                       CC710200
, (
                                                                       02710300
     IMPLICIT REAL+E(A-F.G-Z.1)
                                                                       C0710400
     LOGICAL FG1 . FG2 . FG3 . FG4 . F35 . INCHF . RHLG . LEQU . LINIT(1)
                                                                       CC710500
      LCGICAL
                      METART. LETAPE
                                                                       (0710600
                                                                       C0710700
C
                                                                       C0710800
     INTECER
                                                                      CC7109C0
     . ABCEK . CTI
                  . CT2 . CT3 , CT4 , CT5 , FCUN . FCCN . C0711000
                                   . SFKOUM, SFK . SFH . SG
     SCNEUM. SCN . SCRDUM. SCR
                                                                   . 00711100
                                   . SKDUM . SK
                                    SUK SPIDUM SPI SQF
            . 516
                   . SIXDUM, SIX
                                                                      (9711200
                                                                      CC711300
     . SNA
            . SMC JUM. SMC . SMV
     . SCL
            . SR . SECN . SSIX . SVA
                                           . SVB . SVD . SVI
                                                                      CC711400
                                                                   .
           . SVP
            SVP SVQ SXF SXT TORQ SMAL SEU
                                                                  . 00711500
     . SVM
                                                                      00711600
     . 50
                                   . SU
                                           . SCXC(20)
     · IINIT(1)
                    . IZINIT(1)
                                                                       (0711700
                                                                      CO711800
c
                                                                       CC711900
     REAL OH
                                                                       CC712000
     • ANGC (33) , CNF (3.10) , ETIC (3.10) , 
• FLO (3.20) , FLE (3.3.20), FLH (3.3.20),
                          (3.10) . ETIC (3.10) . ETMC (3.10) . CO712100
                                                                       00712200
                                                  . RZINIT(1)
                   . YMCD (3.2.11). HINIT (1)
     • THACD (23)
                                                                       CC712300
                                                                       C0712400
0
                                                                       C0712500
     CONMEN / CHEKS/
                            NSTART. LRTAPE
                                                                       C0712600
C
                                                                      (0712700
                                                                      CC712800
C
     CCMMCN /LUGIC/ FG1. FG2. FG3. FG4. FG5. INERF. RBLU(10)
                                                                      C0712900
                                                                      CC71 3000
C
                                                                      CO713100
     COMMEN /INTG/
                                                                      CO 71 3200
                      ADDRK (200)
                                   . CT3
     . CT1
                    . CT2
                                                   . CT4
                                                                      C07133CG
                                                                   . (0713400
                                   . JCGN (10)
                    . FCON (22)
                                                   . LCON (22)
     · C15
          (10) . NEI
                                                                   . (0713500
     . MC
                                                   . NCTC
```

```
. AFRC
                                      . NFRC
     . NFER
                                                       . NLCH
                                                                           CO713600
                     . AMD
                                                       . NSVP
                                      . NMOA
                                                                           C0713700
     . NPV
                                                       . SFF
                      . PCCN (11)
                                                                            C0713800
     . NEVC
                                       . 50
                                                                (33)
                     . 51
                                                       . SL
     . 50
                              (55)
                                      . 516
                                                                            C0713900
                                                       . SQF
     4 SLK
              (33)
                     . SHA
                              (10)
                                      . SCK
                                               (11)
                                                                (11)
                                                                           CC714000
                     . SMY
                                                       . SSCN
                                                                            C0714100
     . SCL
             (11)
                                      . SH
                      . SVA
                                                       . SVD
     . S51x
                                       · SVB
                                                                            CO 714200
                      . SVM
                                       . SVP
                                                       . SVO
                                                                            C0714300
                                               (22)
                                                                (33)
     • SVI
                                                       . SMAL
     . SXM
              (3.10)
                     . SXT
                                       . TORG (+7)
                                                                           CC 71 4400
                                               (33)
                                                       . SCG
     . SEU
                      . ATQ
                                       . SC
                                                                           C0714500
                      . SFLX
     · NFL >d
                                       . SFXM
                                              (10)
                                                       . AMODS
                                                                           CC71460C
                      . SCC
     · SFCC
                              (10)
                                                                            CC714700
                                                                            C0714800
C
                                                                            C0714900
      CCHMEN / INTUZ/
                                                                            C0715000
                                                       . SCF
     . SCNELM
                     . SLN
                              (5)
                                      . SLRDUM
                                                                (9)
                                                                            CC715100
     . SFKCL4
                     . SFK
                                      . SIXDUM
                                                       . SIX
                                                                            C0715200
                              (5)
                                                                (9)
                     . SK
     . SKOLM
                              (5)
                                       . SPIDUM
                                                       · SPI
                                                                (9)
                                                                            CO715300
                      . SHC
     . SMCCUM
                              (5)
                                                                            CO 71 5400
C
                                                                            C0715500
C
                                                                            CO 71 5600
      CCHMCA /REAL/
                                                                            C0715700
                                               (10)
     . ..
             (3.10) . CAC
                              (3.10) . CLM
                                                       . CCMC (3.11) .
                                                                            00715800
             (2.11) · ETC
(3.66) · F
                                                               (3.11) .
                                                       . FOMC
     . DCMC
                              (2.11) . ET#
                                               (43)
                                                                           C C 71 590C
     . ...
                                      . ..
                                               (3.10)
                                                      . HMC
                                                                (3.10)
                                                                            CC716000
                     . PHI
                                      . PLM
                                                       . QF
             (10)
     . ....
                              (2.11)
                                                                            CC716100
                                               (10)
                                                                (3.33)
                                                              (3.11) .
     · QFC
             (3.35) . GL
                              (3.22) . OLC
                                               (3.22) . RCMC
                                                                            CC716200
                                                       . THAD
     . T
                                        THA
                                               (33)
                                                                (33)
                                                                            CC716300
                     . THAM
             (10) . THAM (10)
                                     . XDIC
     . THAC. (10)
                                               (J.J.00). XI
                                                                (3.3.10).
                                                                            C0716400
     · XIC
                                      . XMA
                                               (33.33) . XMT
                                                                (3.3.10).
                                                                            C0716500
                              (3.20) . FLd
             (23) . FLA
                                                                (3.20) .
                                               (J.20) . FLC
     . TLG
                                                                            CC716600
     • FLD (3.3.20). FLJ (3.3.23). CAU (3.10) . XIG (3.3.10). • FLIFC (3.10) . FLCRC (3.10) . FLAC (3.20) . FLQC (3.20) .
                                                                            C0716700
                                                                            CC 71 6800
     . FLON
                   . ZETA (20) . FCF
                                              (J.J.40) . FCR
             (20)
                                                                (3.40)
                                                                            CC716900
     CASMIT .
                                                                            C0717000
C
                                                                            C0717100
                                                                            C0717200
C
     CCHMCH /FEAL Z/
                                                                            C0717300
                              (2.10) . COCDUM(1.3)
                                                                (3.10) .
     • CEDLM (1.3) . CH
                                                       . CBC
                                                                            CO 71 7400
     • XMCCLM(1.1.9) . XMC (2.3.13). CBN(3)
                                                                            C0717500
C
                                                                            C0717600
                                                                            C0717700
C
      EQUIVALENCE (ETM(1). THACE(1))
                                              . (XMN(1.1) . ANGD(11)
                                                                            CC717800
                   (XMN(1.3). YMCC(1.1.1))
                                              . (XMN(1.6).CNF(1.1))
                                                                            CC717900
                   (XMN(1.8).ETIC(1.1))
                                              . (XMN(1.10).ETMC(1.1)) .
                                                                            CC718000
                   (FLB(1.1).FLU(1.1))
                                              . (FLE(1.1.1).FLU(1.1.1)).
                                                                            CC718100
                  (FLH(1.1.1).FLJ(1.1.1))
                                                                            CO 71 8200
                                              .(CA(1.1).RINIT(1))
                   (FGI.LINIT(1))
                                                                            CC718300
                  (CODUM(1.1).FZ[K[T(1))
                                             . (ABURK(1). IINIT(1))
                                                                            CC 71 8400
                   (SCNDUP. IZINIT(I))
                                             . (TUHG(78) . SCXC(1))
                                                                            CC 718500
                                                                            CO 71 8600
C
                                                                            CO 71 e 700
     CIPENSICK MESS(18)
                                                                            CO 71 8800
      INTEGER PON(4), SFRMI. SIK
                                                                            CC718900
      CIMENSICA OFK(3.3)
                                                                            CC719000
      INTECER $1(10).52(10).53(10).3ML.34(33)
                                                                            CD 71 91 00
      LOCICAL CTAIN
                                                                            CC 21 9200
e
                                                                           CC719300
C
                                                                           CO719400
                                                                           CO 71 9500
     CATA INH. IDU. LAS/ 'INER' . 'ECCY' . 'ASET'/.
```

```
IXM.IIC.ICE.ICO/'X ','IXC ','CEN ','CCR '/.
                                                                             (0719600
           IEL.ICL.IVT. IFF. ILO/'ELLE'. 'COLX'. 'VTIN', 'FREE'. 'LOCK'/.
                                                                            CC719700
           ICF . IMA/'CFCR' . 'MCMA'/.
                                                                             CC719800
           LVA/'VARE'/.
                                                                             CC719900
           ISM/'SMAL'/.
                                                                             C0720000
     .
            IEN/ ENDI/.
                                                                             00 720100
           NJ . 18L . 1CG/' NO '.'
                                   '. 'CAGE'/.
                                                                             00720200
           IFL . IND / 'FLE X' . 'MCDE '/
                                                                             C0720300
C
                                                                             C0720400
C
      CEFALLT CONDITIONS
                                                                             (0720500
C
                                                                             C0720600
C
      SET UP CETION DATA SETS PAKING NO ENGINEERING ASSUMPTIONS AND THAT CO72C700
          COMPLIATION IS RELATIVE TO INERTIAL FRAME
C
                                                                             CC720800
C
      INERF = .FALSE .
                                                                             00721000
      CO 1 L=1.NBG3
                                                                             C0721100
      I = L-1
                                                                             00721200
      SFK( 1) = 0
                                                                             CO 721300
      SPI(1) = SK(1)
                                                                             C0721400
                                                                             C0721500
      51×(1) = 5K(1)
      SCN(1) = SK(1)
                                                                             CO 721600
    1 SCF(1) = SA(1)
                                                                             C0721700
      5x1 = 5K(0)
                                                                             C0721800
      SVC = SK(2)
                                                                             CC721900
      SMAL = C
                                                                             CC722COO
      SEL = 3
                                                                             CO 72210C
      MERC = MEER
                                                                             C072220C
      ACTC = C
                                                                             CO 722300
                                                                             CC722400
      MEA = 3
      NFKC = C
                                                                             C0722500
      SCC = )
                                                                             CC 722600
      N#2 = 3+N#1
                                                                             CO 722 700
      CO E4 1=1.NB3
                                                                             C0722800
      SLK(1) = 0
                                                                             00722900
   E4 SC(1) = C
                                                                             CC723000
                                                                             00723100
      SFLX = C
      PMCDS = C
                                                                             C0723200
      CO 75 1=1. NBOD
                                                                            CO723300
   75 SF XM(1) = 0
                                                                             CC723400
      NFLXE = C
                                                                             00723500
      SFCC = C
                                                                             CO723600
      QUBA . 354
                                                                             C0723700
      CC 85 1=1.No2
                                                                             CC 72380C
                                                                            CC723900
   85 SCXC(1) = 0
      00 2 I=1.NFER
                                                                             C072400C
                                                                            CC 724100
    2 SFR(1) = 1
      CO 60 1=1.NMD
                                                                             00724200
      SMA(1) = 0
                                                                            CO 724 300
                                                                             C2724400
   60 51(1) = 1
      CALL CENFACISI . NMC . SMV)
                                                                             CO 724500
                                                                            C0724600
      AMV : ANC
                                                                            C0724700
C
                                                                            CO724800
      NOTE
C
          CCRICLIS EFFECTS GALY FOR LINEAR JSCILLATURS
                                                                            CC724900
C
                                                                            CC725000
           INERTIA CROSS COUPLING CNLY FOR RIGIC ECUIES
C
          FCR LINEAR USCILLATUR THANSFORMATION MATRICES FIXED
                                                                            00725100
C
      SUETRACT THESE FRED NON-AUGDENTED SETS CUNSTRUCTED
                                                                            C0725200
C
                                                                             CC725300
      CO 5 L=1.NOUC
                                                                            CC 725400
      1 = L-1
      CALL UNPAL(SI.NI.SCR(I))
                                                                            00725500
```

```
C0725600
      CALL UNPACISZINZISL)
      N3= C
                                                                               CC725700
      IF (N1.= C.0) GU TO 666
                                                                               00725800
      CO & J=1.N1
                                                                               CC725900
       IF (NE.EC.0) GO TO 667
                                                                               CC726000
      CC 668 K=1.N2
                                                                               C0726100
      1F($1(J).NE.S2(K)) GO TC 668
                                                                               CO 726200
      N3 = N3 + 1
                                                                               CO726300
      £3(N2) = $1(J)
                                                                               CC726400
  MEE CENTINUE
                                                                               00726500
  667 CONTINUE
                                                                               CC 726600
    & CENTINUE
                                                                               CC726700
  SEE CONTINUE
                                                                               CC 726800
      CALL CUMFAC(S3.N3.SCF(I))
                                                                               C0726900
    E CENTINUE
                                                                               00727000
C
                                                                               C0727100
                                                                              CO 72720C
      CO 1 ( L=1. NB OD
      I = L-1
                                                                               CC727300
                                                                               CC 72 74 CO
      (ALL LNFAC(SI.NI.SIX(I))
      (ALL UNPAC(SZ.NZ.SH)
                                                                              CO 727500
      A3 = C
                                                                              CO 727600
      1F (N1.EG.C) GO TO 1111
                                                                              C0727700
      CO 11 .=1.N1
                                                                               50727800
      IF (N2.EG.0) GU TO 1112
                                                                              CC727900
      CO 1113 K=1.N2
                                                                               00085700
      IF (51(J) .NE . 52(K)) GC TO 1113
                                                                              CO 728100
      N3 = N3 + 1
                                                                               C0728200
      53(N3) = 51(J)
                                                                              C0 728 300
 1113 CONTINUE
                                                                              CC728400
 1112 CENTINUE
                                                                              C0728500
   11 CONTINUE
                                                                              00728600
                                                                              C0728700
 1111 CONTINUE
      CALL CEMPAC(SJ,N3.SIX(I))
                                                                              CC72880C
   IC CONTINUE
                                                                              CC728900
                                                                              CC729000
                                                                              CC729100
C
   12 READ ICC. ICDI.ICC2. ICD3.1.NSET. (SI(J).J=1.10)
                                                                              00729200
      CT1 = CT1 + 1
                                                                              00729300
      IF (ICOL.EU.IBL) GC TO 20
                                                                              C0729400
      IF (ICCI.EG.NU) GC TO 21
IF (ICCI.EU.IEN) GC TO 21
                                                                              00729500
                                                                              C0729600
   20 IF (1002.EQ. IAS) GC TO 22
                                                                              C0729700
      IF (ICO2.EG.IEU) GC TO 23
                                                                              C0724800
      IF (ICO2.EO.ICL) GC TO 24
                                                                              C0729900
      IF (ICC2.EU.IVT) GC TU 25
                                                                              00730000
      IF (ICO2.EQ. IFR) GC TO 26
                                                                              C0730100
      IF (ICC2.EU.ILC) GC TO 27
                                                                              00730200
      IF (ICD2 . EU . I MA) GE TC 28
                                                                              CO 730 300
      IF (ICO2.EU.ICF) GC TG 29
                                                                              C0730400
      IF (I CD2 . EU . I NA ) GC TC 30
                                                                              00730500
      IF (1002.E0.180) GC TO 31
                                                                              (0730600
      IF (ICC2 . EU . I VA) GC TO 62
                                                                              CC 730700
      IF (ICO2.EU.ISM) GC TO 69
                                                                              C0230800
      IF (ICC2 . EU . ICG) GC TO 77
                                                                              CC730900
                                                             11:
      IF (ICO2 .EQ . IFL) GC TO EC
                                                                              C0731000
      IF (ICCZ.EU. IMD) GC TO 90
                                                                              CO731100
   37 FRINT 200. CTI.ICDI.ICDZ.ICD3
                                                                              CC731200
      FG3 = .FALSt .
                                                                              CO 731 300
      FE TUEN
                                                                              CC731400
   30 INERF = .TRUE.
                                                                              C0731500
```

```
CC 731600
       60 TC 12
   31 INERF = .FALSE .
                                                                              C073170C
      6C TC 12
                                                                              C0731800
   22 IF (ICC3 . EG . IXM) GC TO 32
                                                                              CC731900
       IF (1CD: .EQ . LIC) GC TO 33
                                                                              CC732000
       IF (1(03.EQ.1CE) GC TO 34
                                                                              C0732100
       IF (1CC3.EU.1CO) GC TO 35
                                                                              CC732200
       60 TC 37
                                                                              CC732300
   23 CALL COMPAC(SI.NSET.SEL)
                                                                              C0732400
       GO TC 12
                                                                              C0732500
C
                                                                             00732600
   HC NFLXE = NSET
                                                                             C0732700
      CO 81 1=1.NBUD
                                                                             C0732800
       SF >M(1) = S1(1)
                                                                              CC732900
                                                                             CC733000
   81 NMCDS = NMODS + SFXM(1)
      CREATE THE SET SELX
                                                                             C0733100
       0 = 11
                                                                             C0733200
      CO 96 1=1.NdUD
                                                                              C0733300
      51(1) = 0
                                                                             20455502
       IF (SFXM(I).EQ.O) CC TO 88
                                                                             CC 733500
      11 = 11 + 1
                                                                             CO73360C
      S1(11) = 1
                                                                             C0733700
   BE CONTINUE
                                                                             CC233800
      (ALL COMPACISI .NFL XB . SFL X)
                                                                             CC733900
      READ IN ALL FLEXIBLE SCOY MCOAL DATA
C
                                                                             C0734000
      CALL UNPAC(SI.NSI.SFLX)
                                                                             C0734100
      MN = C
                                                                             (2734200
      MM = 3
                                                                             CO 734300
      FRINT 201
                                                                             CC 734400
      FRINT 242. (SI(I).I=1.NS1)
                                                                             CC 734500
      CC 85 11=1.NS1
                                                                             CO734600
      I = $1(N$1+1-11)
                                                                             C073470C
      READ 103, N. (MESS(J) . J=1 .18)
                                                                             CC73480C
      FRINT 241. N. (MESS(J).J=1.18)
                                                                             CC73490C
      IF (I.EG.N) GC TO EE
                                                                             CC73500C
      FRINT 232
                                                                             20735100
      FG3 = .FALSE .
                                                                             (0735200
      RETUEN.
                                                                             CC735300
   EE SFOMI = SFXM(I)
                                                                             CC 73540C
      CO 87 M=1.SFXMI
                                                                             00735500
      ... . . . . . . .
                                                                             CO 735600
      NN = NN+1
                                                                             C0735700
      READ 134. FLUM(MN). ZETA(MN)
                                                                             (0735800
      READ 104. THA (NEER+MN) . THAC (NEER+MN)
                                                                             C07359CC
      READ 134. (FLA(K.MN).K=1.3)
                                                                             C0736000
      READ 104. (FLU(K.MN).K=1.3)
                                                                             CC736100
      READ 134. (FLC(K.MN).K=1.3)
                                                                             C0736200
      READ 104. ((FLD(K.L.MN).L=1.3).K=1.3)
                                                                             CO 736 30C
      READ 104. ((FLJ(K.L.MN).L=1.3).K=1.3)
                                                                             C0736400
      PRINT 233. MA. MN.FLCM(MA). MN.ZETA(MN)
                                                                             CC73650C
      MENN = NEER + MN
                                                                             20736600
                                                                             C07367CC
      FRINT 235, NEMN, THA (NEMN), NEMY, THAU (NEMN)
      PR INT 234. MN. (FLA(K.MN) . K=1.3) . I
                                                                             00736800
      FRINT 243
                                                                             C073690C
                                                                             C0737C0C
      FR INT 235. MN. (FLE(K.MA) . K=1.3) . I
                                                                             C0737100
      FRINT 243
                                                                             00737200
      FRINT 236. MN. (FLC(K.MN) . K=1.3) . [
      PHINT 243
                                                                             CC 737 30C
      FRINT 236.
                   (FLC(1.L.MA).L=1.3)
                                                                             C0737400
      FRINT 237. MN. (FLC(2.L.MN).L=1.3).1
                                                                             C0737500
```

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FR IN1 236.
                    (FLC(3.L.MA).L=1.3)
                                                                            C0737600
      FRINT 243
                                                                            C073770C
                                                                            C0737800
      PR IN1 23E.
                    (FLJ(1.L.MA).L=1.3)
                                                                            CC737900
      PRINT 240. MN. (FLJ(2.L.MN).L=1.3).1
      FR IN1 23E.
                  (FLJ(3.L.MA).L=1.3)
                                                                            CC738000
      PRINT 215
                                                                            C0738100
      IF (WHM.NE.2) GO TC ET
                                                                            C0738200
      PRINT 2C1
                                                                            CO7383CO
     ---
                                                                            C0738400
   87 CONTINUE
                                                                            C0738500
                                                                            C0738600
   EE CUNTINUE
                                                                            C0738700
      GC TC 12
                                                                            CO 738800
C
C
      CONSTRUCT CENTRIPETAL AND CORIJLIS MODE COUPLING CODE WORD
                                                                            CC738900
   9C CONTINUE
                                                                            C0739000
      CHECK IF 'FLEXIBLE' HEAD YET
                                                                            C0739100
      IF (NEODS .NE . 0) GU TO 91
                                                                            C073920C
  154 PRINT 232
                                                                            CO 739300
     FG3= .FALSE .
                                                                            C0739400
      FE TUEN
                                                                            CC 239500
   91 CG 92 1=1.NMCDS
                                                                            CC 739600
   92 SCXC(1) = 0
                                                                            C07397C0
     CO 93 1=1.NBCD
                                                                            C073980C
  93 S2(1) = C
                                                                            CC739900
                                                                            CC740C00
     NS2 = 0
      CO 94 J=1.NBOD
                                                                            C0740100
      IF ($1(J).EQ. C) GO TO 94
                                                                            C0740200
      NS2 = NS2+1
                                                                            CO740300
                                                                            CO 740 400
      $2(N$2) = J
   94 CONTINUE
                                                                            C0740500
      (ALL COMPAC($2.NS2.SFCC)
                                                                            C0740600
      FRINT 2C1
                                                                            CC740700
      FRINT 244, ($2(1),1=1,NS2)
                                                                            CO74080C
     READ IN MUDE COUPLING DATA. SET UP COUNTERS
                                                                            CC740900
     WN = 0
                                                                            C0741000
     KF = 0
                                                                            CO 741100
     CO 150 K=1.NBOD
                                                                            C0741200
      IF (SFXM(K).EQ.O) GC TO 150
                                                                            CO741300
      IF (S1(K).NE.C) GU TO 151
                                                                            C0741400
                                                                            CC741500
     NO CRESS COUPLING TERMS. UFCATE MUDE NUMBER COUNTER MN
     MN = MN+SFXM(K)
                                                                            CC741600
      GO TC 150
                                                                            C0741700
  151 51K = 51(K)
                                                                            0741800
      CO 152 1=1.51K
                                                                            C0741900
     READ 105. MO.NO.KE
                                                                            C0742000
      IF (K.NE.KB) GO TO 154
                                                                            C0742100
     MNA = MA + NP
                                                                            CO 74 2200
     (ALL UNPACISZINSZISCXC(MAN))
                                                                            C0742300
     NS2 = NS2+ 1
                                                                            C0742400
      52(NS2) = MB
                                                                            CO 74 2500
      CALL CUMPAC(52.NS2.SCXC(PNN))
                                                                           00742600
     KF = KF+1
                                                                           CC 742 700
     READ 104. ((FCF(11.JJ.KF).JJ=1.3).11=1.3)
                                                                            CC742800
     FRINT 243
                                                                           C0742900
                                                                           CC74 3000
     FRINT 246.
                          (FCF(1.JJ.KF).JJ=1.3)
     PRINT 247, Mb.NJ.KE. (FCF(2.JJ.KF).JJ=1.3).K.KF
                                                                           CO 74 3100
     FRINT 246.
                          (FCF (3.JJ.KF).JJ=1.3)
                                                                           CO743200
     FRINT 243
                                                                           C0743300
                                                                           C0743400
     FEAD 134. (FCK(II.KF). [[=1.3)
     FR [N1 24E. ME,NB.KE. (FCK (JJ.KF).JJ=1.J).K.KF
                                                                           C0743500
```

```
FRINT 243
                                                                             (0743600
  152 CONTINUE
                                                                             CC743700
       CHECK AND OUTPUT INTEGER ARRAYS FOR BODY K
                                                                             CC743800
      KKF = KF-SI(K)
                                                                             C0743900
      SFXMI = SFXM(K)
                                                                             CC744000
      CO 153 I=1.5FXMI
                                                                             CO 744100
      MN = MN+1
                                                                             C0744200
      (ALL UNPAC(52.NS2.SCXC(MA))
                                                                             CO744300
      IF (NS2.NE.0) GU TO 155
                                                                             CC744400
      FRINT 243
                                                                             CO744500
      FRINT 245. MN
                                                                             CO 744600
      60 TC 153
                                                                             CO 744700
  155 CO 150 J=1.NS2
                                                                             CC744800
      NB = $2(N$2+1-J)
                                                                             CC744900
      KKF = KKF+1
                                                                             C0745000
      FRINT 25C. K.MB.MN.KKF
                                                                             CC745100
  156 CONTINUE
                                                                             C0745200
  153 CUNTINUE
                                                                             CO 745300
  150 CONTINUE
                                                                             CC 745400
      CO TC 12
                                                                             CC 745500
C
                                                                             CC 745600
   24 CALL COMFAC(SI.NSET.SXT)
                                                                             C0745700
      60 TC 12
                                                                             C0745800
   25 (ALL CLMFAC(SI.NSET.SVC)
                                                                             CC 745900
      CO TC 12
                                                                             C0746000
   62 CALL CEMPAC(SI .NSET .SMV)
                                                                             CC 746100
      MMV = NSET
                                                                             C0746200
      CC TC 12
                                                                             CO746300
   65 CALL CEMPAC(SI . NSET . SMAL)
                                                                             C0746400
      GO TC 12
                                                                             CO 746500
   77 SCC = NSET
                                                                             CO 746600
      CO 95 1=1.5CG
                                                                             C0746700
      READ 101. SC(1).TEM
                                                                             C0746800
   99 TUC(SC(11) = TEM
                                                                             CC 746900
       CHECK IC UN THAD (SC(1)); MUST DE ZERU. RESET IF NUT.
                                                                             CC747000
          CODING FOR IMPULSE EFFECT DUE TO NON-ZERO THAD NOT INCLUDED
      DU 78 1=1.5CG
                                                                             CO 74 7200
      IF (THAU (SC(1)).EQ.C.O) GC TC /d
      THAD (SC(1)) = 0.0
                                                                             CC 74 740C
      FRINT 230. SC(1)
                                                                             C0747500
   70 CONTINUE
                                                                             C0747600
      CU TC 12
                                                                             CC747700
   et CTE = CTE+1
                                                                             CC747800
      JDENE = CT2+NSET-1
                                                                             CC747900
      IF (C12.G1.JUCNE) GC TC SCOL
                                                                             CC748000
      CO 3E J=CT2. JOUNE
                                                                             C0748100
   16 SFH(J) = 51(J+1-CT2)
                                                                             CO 748200
 STOL CONTINUE
                                                                             CO 748300
      CT2 = CT2+NSET-1
                                                                             CO 748400
      CC TC 12
                                                                             CO748500
                                                                             CC748600
  27 (13 = 013+1
      JOCNE = CTJ+NSET-1
                                                                             C0748700
                                                                             CC 74880C
      IF (C13. GT. JOENE) CC TO 5002
                                                                             C0748900
     CU 35 J=CTJ. JOONE
" 35 SLK(J) = 51(J+1-CT3)
                                                                             00749000
                                                                             C0749100
SOCE CENTINUE
      CT3 = CT3+NSET-1
                                                                             CO 74 9200
      CC TC 12
                                                                             C0749300
   28 CT4 = LT4+1
                                                                             CO 74 94 0C
      DENE = CT4+NSET-1
                                                                             CO 74 9500
```

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C0749600
       IF (C14.GT.JUENE) GC TG 5C03
      CO 4C J=CT4. JOONE
                                                                             C0749700
   40 SMA(J) = S1(J+1-CT4)
                                                                             CC749800
                                                                             C0749900
 SOOS CONTINUE
                                                                             CC750000
      CT4 = CT4+NSET-1
                                                                             C0750100
      60 TC 16
                                                                             C0750200
   29 CTE = CTS+1
      JDENE = CT5+NSET-1
                                                                             C0750300
      IF (C15.G1.JDCNE) GO TO 5004
                                                                             C0750400
      DO 41 J=CT5. JEONE
                                                                             C075C500
                                                                             C0750600
   41 SFK(J) = 51(J+1-CTE)
                                                                             C0750700
 5004 CENTINUE
                                                                             CC75C800
      CTS = CTS+NSET-1
                                                                             CC750900
      GO TC 12
                                                                             CO 751 000
   32 CALL CEMPAC(SI .NSET . SPI(I))
                                                                             C075110C
      60 TC 12
                                                                             C0751200
   33 CALL COMPAC(SI, NSET, SIX(I))
                                                                             CC 751 300
      GD TC 12
                                                                             C0751400
   34 (ALL COMFAC(SI .NSET. SCA(I))
                                                                             C075150C
      GO TC 12
                                                                             C0751600
   35 CALL CLWFAC(SI.NSET.SCR(I))
      GO TC 12
                                                                             C0751700
                                                                             C0751800
   21 CT1 = 0
      IF (C12.EG.0) GC TC 42
                                                                             CC751900
      NFHC = CT2
                                                                             C0752000
                                                                             C0752100
      c = sto
   42 IF(C13.EG.3) GU TC 43
                                                                             CO 75220C
      NCTC = CT3
                                                                             C0752300
                                                                             CO 752400
      (13 = )
   43 IF (C14.EG.O) GO TC 44
                                                                             CC75250C
      MMCA = CT4
                                                                             C0752600
                                                                             C0752700
      CT4 = 3
   44 IF (CTE.EG.O) GC TC 45
                                                                             C0752800
      AFKC = C15
                                                                             C0752900
      (TE = )
                                                                             CC75300C
                                                                             C0753100
   45 CONTINUE
C
                                                                             C0753200
C
                                                                             C0753300
      CHIAIN CLEMENTS UF ARRAY SXM
                                                                             C0753400
C
C
       INITIALIZE BUTH SAM AND TH ARRAYS
                                                                             CC753500
                                                                             CO 75 3600
      CC 3 K=1.NBCD
      CO 3 1=1.3
                                                                             C0753700
      SXM(1.K) = 0
                                                                             C0753800
                                                                             C0753900
    3 CENTINUE
      DEFINE CONTIGUOUS PAIRS FOR WHICH DIRECTION COSINES ARE TO BE USEDCO754000
C
      SD = SR-SMAL-SEU
                                                                             00754100
       DEFINE CONTIGUOUS PAIRS FOR WHICH SMALL ANGLE UR EULER ANGLE
                                                                             C0754200
C
                                                                             C0754300
        TECHNIQUES TO BE USEC
C
                                                                             C0754400
      SML = JA - 50
                                                                             C0754500
      CALL UNPAC(SI.NSI.SML)
C
      CYCLE THROUGH ELEMENTS OF SML TO DEFINE SXM ARRAY
                                                                             C2754600
      IF (NSI.EG.C) GO TC 5080
                                                                             C0754700
                                                                             C0754800
      DO 4 AK=1.NS1
      K = 51(KK)
                                                                             CC754900
      CEFINE NEMINAL STATE TRANSFORMATION FROM BODY JCCN(K) TO BODY K
                                                                            C0755300
      CALL TANSPS (XMT(1.1.K))
                                                                             C0755100
                                                                             CC755200
      PICK OUT GIMEAL CONFIGURATION AT HINGE PUINT K-1
                                                                             C0755300
      IGCTC = FCCN(K) + 1
      CO TC (13.14.15.16). IGLTC
                                                                             CC755400
                                                                             C0755500
   16 (ALL TRNSPS (XMT(1.1.K))
```

```
CO TC 4
                                                                             C075560C
  15 NGA = J
                                                                             C0755700
     N = SQF(K)
                                                                             C0755600
                                                                             CC 755900
     L = SQL(K)
                                                                             CC756000
     (ALL VECTEN (GF(1.4).XMT(1.1.K).GFK(1.1))
                                                                             C0756100
     CO 75 I=1.3
  75 CFK(1.2) = QL(1.L)
                                                                             00756200
     (ALL VECTOS (QFK(1.1),QFK(1.2),QFK(1.3))
                                                                             00756300
     CC TC 7
                                                                             CO 756400
  14 NGA = 3
                                                                             00756500
                                                                             CC 756600
     N = 94F (K)
     N1 = W+1
                                                                             C0756700
                                                                             CO756800
     CALL VECTEN (GF(1.M).XMT(1.1.K).JFK(1.1))
     CC 8 1=1.3
                                                                             C0756900
   8 GFK(1.2) = GF(1.M1)
                                                                             C0757000
     (ALL VECTOS (QFK(1.1), GFK(1.2), QFK(1.3))
                                                                             CC75710C
     GC TC /
                                                                             C0757200
  13 NGA = 5
                                                                             CO 757300
     N = SUF (K)
                                                                             C075740C
     #1 = M+1
                                                                             CO 757500
     N2 = N+2
                                                                             CC 75 7600
     (ALL VECTHN (UF(1.M).XMT(1.1.K).UFK(1.1))
                                                                             C0757700
     CO 9 1=1.3
                                                                             CO 75 78CO
   5 GFK(1.3) = JF(1.M2)
                                                                             C07579C0
     (ALL VECAUS (GFK(1,3),GFK(1,1),UFK(1,2))
                                                                             C0758000
                                                                             C0758100
     CO TC 7
   7 IF (NGA.EG.J) GO TC 16
                                                                             CC 758200
     CO 17 N=1.NGA
                                                                             CO 75830C
     CO 17 1=1.3
                                                                             CO 75840C
                                                                             CO 758500
     IF (GFK(I.N).NE.O) GO TO 18
                                                                             CC 758600
     CO TC 17
                                                                             CO 758700
  18 IF (OFK( 1.N) . NE . 1) GO TC 19
                                                                             CC 75880C
     1 = ( A. A ) MX ?
     CL TC 17
                                                                             CC 758900
  15 IF (QFK(1.N).NE .- 1) GO TU 58
                                                                             CC 759000
     SXM(N.K) = -1
                                                                             C0759100
                                                                             CC 759200
     CC TC 17
  SE CONTINUE
                                                                             C0759300
     COME FERE UNLY IF FREE COGRETNATE AXES NOT ALIGNED WITH
                                                                             C075440C
                                                                             C0759500
      BODY & FIXED AXES IN NUMINAL STATE.
         SMALL ANGLE OF EULER ANGLE METHOUS CANNOT BE USED. INCLUSION
                                                                            CC 759600
         CF THIS CAPABILITY OF LIMITED VALUE SINCE IT WOULD SACRIFICE CC759700
         CEMPLIATION SPEED AND MEMUNY STORAGE.
                                                                             CC 759800
     PLT K BACK IN SO AND CELETE IT FREM SEU UR SMAL
                                                                             CC75490C
                                                                             C0760000
     52(1) = K
     CALL CENFACESZ.1.NK)
                                                                             C276010C
                                                                            C0760200
     SD = SU + NK
     CALL UNPAC(53.NS3.SEU)
                                                                             CC 760 30C
     IF (N53.EG. 0) GO TO 5020
                                                                            CC 76 040C
                                                                             CO 76C500
     CO 71 --= 1.NS3
                                                                            CC769600
     1 = 53(11)
     IF (J.NL.K) GO TO 71
                                                                             CC 76C7CO
                                                                            CC 760800
     SEL = SEL - NK
                                                                             C076C900
     GO TC 16
'71 CONTINUE
                                                                            C0761000
5020 CONTINUE
                                                                            CC 76110C
                                                                            00761200
     (ALL UNPAC(S3.NS3.SMAL)
     IF (NS3.EG.0) GO TC 16
                                                                            CO 761 300
     CC 72 JJ=1.NS3
                                                                            CO 76 140C
                                                                            C07615C0
     1 = 53(JJ)
```

C

C

C

```
IF (J.NE.K) GO TO 72
                                                                              (0761600
      SMAL = SMAL - NK
                                                                              CC 761 7CO
      GC TC 16
                                                                              C0761800
   72 CONTINUE
                                                                              CC761900
      GO TC LE
                                                                              C0762000
   17 CONTINUE
                                                                              C0762100
                                                                              0762200
      60 TC 16
    4 CONTINUE
                                                                              CO 762300
 SOUC CONTINUE
                                                                              C0762400
                                                                              C0762500
C
      MAKE SURE ALL ANGLES CALLED FUR BY SAM WILL BE CUMPUTED
                                                                              CC762600
      CO 36 K=1. NOUD
                                                                              C0762700
      IF (9>N(1.K).EG.C) GO TC 36
                                                                              C0762800
      NDCNE = 3-PCUN(K)
                                                                              00762900
      CO 45 LL=1.MOCNE
                                                                              CO 76 3000
      L = LL-1
                                                                              00763100
      * = 5GF(K) + L
                                                                              CC763200
      IF (NF4C.EQ.0) GU TC 5021
                                                                              CO763300
      CO 57 N=1.NFRC
                                                                              CC 76 3400
      IF (M.EJ.SFR(N)) GC TO 49
                                                                              CO 76 3500
   57 CONTINUE
                                                                              C0763600
 5021 CONTINUE
                                                                              CC 76 3700
      COME HERE IF M NOT IN SER
                                                                              0763800
      NFRC = NFRC+1
                                                                              CC763900
      SFR(NFRC) = M
                                                                              CC764000
   45 CENTINUE
                                                                              C0764100
   36 CONTINUE
                                                                              C0764200
                                                                              CO764300
      MAKE SURE TRANSLATION COMPONENTS OF C.M. OF BODY 1 (HINGE POINT 0)CC764400
C
C
       ARE CUMPUTED SU AS TO BE ABLE TO DEFINE CB(1). NEEDED FOR INERTIACO764500
       ANGLLAR MEMENTUM AND ENERGY CALCULATION
C
                                                                              C0764600
                                                                              C0764700
      NDCN1 = SQF(NB1)
      MOCNE = SUF(NB1)+2-FCCN(NB1)
                                                                              CC764800
      IF (MCCNI.EJ. C) GU TO 5033
                                                                              CC764900
    .. CC 73 4=MOUNI.MOUNE
                                                                              CC 765000
      IF (NFAL . EQ . 0) GU TC 5722
                                                                              CO 765100
      CO 74 N=1.NFRC
                                                                              CO 765200
      IF (M.EJ.SFR(N)) GC TG 73
                                                                              CO 765 300
   74 CONTINUE
                                                                              C0765400
 SO22 (CNTINUE
                                                                              C0765500
      NEHC = NEHC+1
                                                                              CO 765600
      SFRINFAC) = N
                                                                              CC 765700
   73 CONTINUE
                                                                             CO 765800
5033 CENTINUE
                                                                              CC 765900
C
                                                                             CC766000
C
      MAKE SURE ALL POINT MASS COCHDINATES IN SOF ARRAY
                                                                             C0766100
      CALL UNPAC(SI.NI.EL)
                                                                             CO 766200
      IF (N1.EG.0) GO TO ECIH
                                                                              CO 766300
      CO 96 11=1.N1
                                                                             C0766400
      1 = 51(11)
                                                                             (0766500
      MDCNI = SUF(I)
                                                                             C0 766600
      MDCNE = SUF(1) + 2 - PCCN(1)
                                                                             CC 7667CC
      IF (MECNI.EU. 0) GU TO SCIE
                                                                             C0766800
                                                                         £ C 766900
      CO ST M=MUCNI.MUUNE
      IF (NFRC . EQ . 0) GO TC 5917
                                                                             C0767000
      CU SE N=1.NFRC
                                                                             CO 767100
      IF (M.EJ.SFR(N)) GC TO ST
                                                                             C0767200
  SE CONTINUE
                                                                             CO767300
SOLT CONTINUE
                                                                             CC 767400
      MERC = MERC + 1
                                                                             C0767500
```

```
SFH(NFHC) = N
                                                                             CO 76 7600
   ST CONTINUE
                                                                             C0767700
                                                                             CO 76 7800
 5016 CONTINUE
   SE CONTINUE
                                                                             CC767900
 SOLE CONTINUE
                                                                             CC768C00
C
                                                                             CO 768100
      FIND ALL MUMENTUM WHEELS IN THE NEST K-1; K=1.2....NBOD
C
                                                                             CO 768200
      CC 66 11=1.NEOD
                                                                             C0768300
                                                                             C0768400
      (ALL UNFAC(SI.NI. SK(I))
                                                                             CO 768500
      CO 67 J=1.10
                                                                             CO 768600
   67 52(J) = C
                                                                             CC7687CO
      N2 = C
                                                                             C0768800
      IF (N&U.EC. 3) GO TC 5023
                                                                             C0768900
      CO 6E J=1.NMU
                                                                             C0769000
      IF (.NCI.CTAIN(MU(J).SI.NI)) GJ TO 68
                                                                             C0769100
      N2 = N2 + 1
                                                                             CO 769200
      52(N2) = J
                                                                             CO 769300
   EE CUNTINUE
                                                                             CO 769400
 5023 CCATINUE
                                                                            CO 769500
      (ALL CONFAC(S2.N2.SMC(I))
                                                                             CO 769600
   66 CONTINUE
                                                                             00769700
                                                                            CO 769800
C
      IF CEMPLIING FRAME BODY I DELETE LABEL I FROM SVC
                                                                             CC769900
                                                                            CC770000
      (ALL UNPAC(SI.NSET.SVD)
      IF (INEFF.OR. SI (NSET) . EG.C) GO TO 76
      NSET = NSET - 1
                                                                             C0770200
      CALL CEMPACISI . NSET . SVD)
                                                                             C0770300
   76 CONTINUE
                                                                             CC770400
                                                                            CC77050C
C
C
                         ALL TRUNCATED SUMMATIONS DEFINED
                                                                             (0770600
                              PEINT THEM OUT
                                                                             C07707C0
C
C
                                                                             CO77080C
      PRINT 201
                                                                             C0770900
      IF (INERF) GU TC 46
                                                                             CC771000
      FRINT 203
                                                                             C0771100
   60 TC 47
                                                                             C0771200
                                                                            C0771300
                                                                             CO771400
   47 FRINT EC4
                                                                            (0771500
      FRINT 205
      FRINT 206
                                                                             C0771600
                                                                             CC 771 70C
      CO 48 11=1.NHOD
                                                                            CO771800
      1=11-1
      CALL UNPAC(SI.NSET.SK(I))
                                                                             CO 771900
                                                                            C0772000
      FRINT 207. 1.(S1(J).J=1.ASET)
                                                                             CC 772100
      (ALL UNPAC(SI.NSET.SMC(I))
                                                                            CC772200
      FRINT 222. [.(31(J).J=1.NSET)
      FRINT 224
                                                                            C0772300
                                                                            CO 772400
      CALL UNPAC(31.NSET.SPI(I))
      FRINT 2(5. (S1(J).J=1.ASET)
                                                                            CC772500
                                                                            C0772600
      (ALL UNPAC(SI.NSET.SIX(I))
                                                                             C0772700
      PRINT 210. (SI(J). J=1. NSET)
                                                                            CC772800
      (ALL UNPAC(SI.NSET,SCN(I))
                                                                            C0772900
      FRINT 211. (SI(J).J=1.NSET)
                                                                            CC 77 10CC
      CALL UNPAC(SI.NSET.SCR(II)
                                                                            CC 773100
      FRINT 212. (S1(J).J=1.NSET)
   46 FRINT 2 5. I
                                                                            CC 773200
                                                                            C0773300
      PRINT 201
      (ALL UNPAC(SI.NSET.SD)
                                                                            CO773400
                                                                            CO773500
      IF (NSET.EQ.O) GO TO 5005
```

```
C0773600
     CC 50 1=1.NSET
  5C PRINT 214. SI(1). JCGN(S1(1))
                                                                            CC773700
                                                                            C0773800
     FRINT 215
                                                                            CC773900
SOCE CONTINUE
     (ALL UNPAC(SI.NSET.SMAL)
                                                                            C0774000
     IF (NSET.EU.O) GO TC 50C6
                                                                            CC774100
                                                                            CC774200
     CO 55 1 =1.NSET
  59 FRINT 22E. S1(1). JCCN(S1(1))
                                                                            CC774300
                                                                            C0774400
     PRINT 215
SOCE CENTINUE
                                                                            CO 774500
                                                                            CC 774600
     (ALL UNPACISIONSET.SEU)
                                                                            CC7747C0
     IF (NSET.EU.0) GO TO 5007
     CO 7C I=1.NSET
                                                                            CO 774800
                                                                            CC774900
  7C PRINT 229, SI(I). JCON(SI(I))
     FRINT 215
                                                                            CO 775000
SCC7 CENTINUE
                                                                            CC775100
     (ALL UNPAC(SI.NSE1.SXT)
                                                                            C0775200
     IF (NEET.EG.D) GO TC 5008
                                                                            C0775300
     CC EL I=1.NSET
                                                                            C0775400
  51 FRINT 216.51(1)
                                                                            C0775500
     FRINT 215
                                                                            CC775600
SOCE CONTINUE
                                                                            C0775700
                                                                            CC775800
     (ALL UNPACISIONSET.SVD)
                                                                            C0775900
     IF (NSET.EU.O) GO TC 5709
     CO SE I=1.NSET
                                                                            0776000
                                                                            C0776100
  52 FRINT 217.51(1)
     FRINT 415
                                                                            C0776200
5009 CONTINUE
                                                                            CQ 776300
     FUT AHRAY SER IN SEQUENTIAL CHOER
                                                                            C0776400
     CO 61 1=1.NB3
                                                                            C0776500
  £1 54(1) = C
                                                                            C0776600
     IF (NFRC .EQ.O) GO TC 5010
                                                                            C0776700
                                                                            C0776800
     CO 63 1=1.NFRC
  63 S4(SFR(1)) = 1
                                                                            C0776900
                                                                            C0777000
SOIC CONTINUE
                                                                            CC 777100
     K = C
                                                                            CC777200
     CO 64
            I=1.N83
     IF (S4(1).EU.C) GL TO 64
                                                                            C0777300
     K = K+1
                                                                            CC777400
                                                                            CC77750C
     SFF(K) = 1
                                                                            CC777600
  64 CONTINUE
     IF (NFHC . EQ . O) GO TC 5011
                                                                            CO 777700
                                                                            C0777800
     DO 53 I=1.NFRC
  53 FR INT 216. SFR(1)
                                                                            CO 777900
                                                                            CC778000
     PRINT 215
                                                                            C0778100
SOLL CONTINUE
                                                                            CQ 77H2QQ
     IF (NCTC.EU.O) GO TO 5012
                                                                            C0778300
     CO 54 I=1.NCTC
  SA PRINT 215. SLK(1)
                                                                            CO 7764CO
                                                                            CO778500
     PRINT 215
SOLE CONTINUE
                                                                            CC 778600
                                                                            CO 778700
     IF (NFKC.EU.0) GO TC 5013
     DO SE IST.NEKC
                                                                            C0 778800
  55 FRINT 22(. : FK(I)
                                                                            CO 778900
                                                                            C0779000
     PRINT 215
                                                                            C0 779100
5013 CONTINUE
                                                                            C0779200
     (ALL UNPACISIONSET.SAV)
                                                                            C0779300
     IF (NSET.EJ.0) GO TC 5014
                                                                            C0779400
     CO 65 1=1.NSET
                                                                            C0779500
 65 FRINT 213. SI(1)
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FRINT 215
                                                                          CC779600
5014 CCATINUE
                                                                          CC7797CO
     IF (NDCA . EQ. 0) GO TC 5015
                                                                          C0779800
     CO SE I=1.NMOA
                                                                          CO 779900
  SE PRINT 221. SMA(I)
                                                                          CC780000
    FRINT 215
                                                                          CO 78010C
SOIS CENTINUE
                                                                          CO 780200
     IF(SCG.EC.O) GD TD 83
                                                                          CC78030C
     CO 82 1=1.SCG
                                                                          C0780400
 62 FRINT 221. SC(1).TLG(SC(1))
                                                                          CC780500
 83 CONTINUE
                                                                          CC 780600
    CT1 = C
                                                                          CO 780 7CO
 100 FORMAT (3A4.13.1115)
                                                                          CC 780800
101 FURMAT (15.015.5)
                                                                          CC780900
102 FORMAT (15.2015.5)
                                                                          CC781000
123 FORMAT (15.18A4)
                                                                          C0 781 100
104 FORMAT (3015.5)
                                                                          CO 781200
105 FORMAT (£15)
                                                                          CC 781300
200 FORMAT ( * IDENTIFICATION CODE NOT RECOGNIZED IN SUBROUTINE INCPT. CC781400
    *INFUT CFTICN CARD '. IA. ' CCDE READ IS '. JA4)
201 FORMAT ('1')
                                                                          CO 781600
202 FORMAT (10x, "COMPLTING FRAME TAKEN TO BE THAT FIXED INERTIALLY" .// CC781700
   1/1
                                                                          C0781800
203 FURNAT (10x, 'CCMPLTING FRAME TAKEN TO BE THAT FIXED IN BUCY 1'.///CC781900
   . )
                                                                          CC792000
204 FORMAT (30%, TU SPEED UP COMPUTATION VARIOUS TRUNCATED SETS OF BODGO782100
   TY LAEELS HAVE BEEN DEFINED!)
                                                                          CC782200
205 FORMAT (34x, 'THE SPECIFICATION OF THESE SETS PERMITS ENGINEERING JC0782300
   SUDGERENT TO!
                                                                          CO 782400
206 FORMAT (38x, 'BE INTRODUCED INTO THE FURMALISM AND MODELLING 1.///)C0782500
207 FORMAT (30x, 'BODY LABELS OF EUDIES IN NEST'.13.3x.1015)
                                                                          C078260C
2CE FORMAT (2CX.1CIS./)
205 FORMAT (30x, 'PSUEDC INERTIA TENSORS', 13x, 1015)
                                                                          CC 78280C
21C FORMAT (30x. 'INERTIA CROSS (CUPLING'. 13x. 1015)
                                                                          CC782900
211 FORMAT (JOX. 'CENTRIPITAL CROSS COUPLING'. 9X.1015)
                                                                          CC 783000
212 FORMAT (30x, 'CURICLIS CRESS COUPLING', 12x, 1015)
                                                                          CC7831CO
213 FORMAT (10x, 'MCMENTUM WHEEL', 13, ' 15 ASSUMED TO BE VARIABLE SPEED CO783200
   ...
                                                                          CO 78330C
214 FORMAT (10x, 'RELATIVE ANGULAR DISPLACEMENT LETHERN HODIES', 13, 'ANCO783400
   .C'.13.' IS COMPUTED VIA INTECHATION OF DIRECTION COSINE EQUATIONS CO 783500
                                                                          CC 78360C
215 FORMAT (////)
                                                                          CO 783700
216 FORMAT (10x, 'THE ELEMENTS OF CULUMN', 13. LOWN TO THE CIAGONAL IN CC783800
   OTHE SYSTEM INERTIA MATRIX OF DYADS ARE ASSUMED TIME VARYING!)
                                                                         CC78390C
217 FORMAT (10x, 'VECTORS AND DYADS FIXED IN BODY', 13, ' ARE ASSUMED TIMEC784000
   .E VARYING IN THE FRAME OF COMPUTATION ")
                                                                          C0784100
218 FORMAT (10x DISPLACEMENT ACCUT UR ALUNG FREE VECTOH . 13. CEMPUTEDCC784200
                                                                          CC 784 300
   ...
219 FORMAT (10x, *CONSTRAINT 10FQUE ABOUT OR ALONG LOCKED VECTOR*, 13. * CO784400
   OCCUPLIED .)
                                                                          CC 784500
220 FORMAT (10x. 'CCNSTRAINT FORCE AT HINGE PUINT', 13. ' COMPUTED
                                                                     1) (0784600
221 FORMAT (10x, 'ANGULAR POSITION OF MOMENTUM BREEL', 13, ' COMPUTED ') CC784700
222 FORMAT (30x, 'MOMENTUM WHEEL LAUELS IN NEST' . 13.3x . 1015)
                                                                          CC 7848CO
224 FURMAT (20x. PHIME CONTRIBUTORS TO COMPUTATION OF ')
                                                                         CC784900
225 FORMAT (20x. FOR THE EQUATION OF MUTION OF NEST' . 13.////)
                                                                         CC785000
228 FORMAT (13x, 'RELATIVE ANGLIAR DISPLACEMENT BETWEEN BUDIES', 13, ' ANCC785100
  PC'.12. ' IS COMPUTED VIA SMALL ANGLE ASSUMPTIONS ')
                                                                         CC 78520C
229 FORMAT (10x, FELATIVE ANGULAR DISPLACEMENT BETWEEN BUDIES', 13. ANCO785300
   .D'.13. 15 CCMPUTED VIA EULER ANGLE TECHNIQUES ')
                                                                         CC 78540C
230 FORMAT (10x, 'NUTE: THAC(',12,') = ) INITIAL HATE CONDITION RESERVED 785500
```

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231 FORMAT (10x, 'MOTICA ABOUT FREE VECTOR', 13. ' UNCAGED AT T=', C15.5) 00785700
                 MODAL DATA CUT OF SEQUENCE ")
  232 FORMAT ('
                                                                           CC785800
  233 FORMAT ( .
                 MUDE', 13.2x,' FLCM(',12,') =',C12,5,5x,' ZETA(',12,') =(C785900
     **.C12.0)
                                                                           C0786000
  234 FORMAT (' FLA('.12,') ='.3C12.5.3x,' (BUDY'.12,' FIXED COORCINATECO786100
     .5) 1)
                                                                           C0786200
  235 FORMAT ( * FLB('.12.') = '.3012.5.3x.' (BJDY'.12.' FIXED COURD INATECC786300
     . ()
  236 FORMAT ( * FLC('.12,') = '.3C12.5.3x,' (BJDY'.12,' FIXED COORDINATECO786500
     . 5) .)
  237 FORMAT ( FLD('.12.') = '.3C12.5.3X.' (BUDY'.12.' FIXEC COORC INATECO786700
     . (1 (20
                                                                           CC 786800
  236 FORMAT (11x. 3012.5)
                                                                           C07869C0
  235 FORMAT (11x.' THA(',12.') = '.012.5.5x.' THAD(',12.') = '.012.5./) CC787C00
  240 FORMAT (' FLJ(',[2,') =',3012.5.3x,' (@JDY', 12,' FIXED COORDINATE(C787100
     ...
                                                                           C0787200
  241 FORMAT (///.10x.' MODAL DATA FUR BODY'.15.1844./)
                                                                           C0787300
  242 FURMAT (10x. THE FOLLOWING HIDIES HAVE BEEN REDEFINED TO BE FLEXICO787400
     · ELE ' . 1015)
                                                                           C0787500
  243 FCEMAT ( * *)
                                                                           CC 78760C
  244 FORMAT LIGA. THE FULLCOING FLEXIBLE BUDIES HAVE SIGNIFICANT MODE CC787700
     *COLPLING IN THEIR DEFORMATION EQUATIONS*. 1313)
                                                                           CC78780C
  246 FORMAT (174.3012.5)
                                                                           CC787900
  247 FCFMAT (' FCF('.12.','.12.','.12.') ='.JC12.5.' (BUDY'.12.' FIXECCC7880C0
     . CCORCINATES!
                     LCCATEC AT FCF(1.1.1.12.11)
                                                                           CC788100
  246 FORMAT ( * FCK( ', 12 . ', ', 12 . ', ', 12 . ') = ', 3D12 . 5 . ' (UCDY ', 12 . ' FIXEC CO 788200
     . CCORDINATES) LCCATEC AT FCK(1.1.12.1)1)
                                                                           CC788300
  249 FORMAT (' SCXC('.12.') = C') (C78840C
25C FORMAT (' BUDY '.12.' MCDE'.13.' CROSS COUPLES IN CUCHDINATE EGUACO79850C
     ATICH '.IZ.' COEFFICIENTS AT KF ='.13)
                                                                           C0798600
      SE TUEN
                                                                           CC748700
      END
                                                                           CO 788800
                                                                           0000000
C
      SUERCLTINE INTCH
                                                                           COR201CO
                                                                           (0020093)
c
                                                                           CC600300
      INFLICIT HEAL BIA-+ . C-2.11
                                                                           CCF334C0
      LUCICAL FG1. FG2. FG3. FG4. F.S. INERF. ABLU. LEUU. LINIT(1)
                                                                           CORDOSOC
      LOCICAL
                        METART. LETAPE
                                                                           COR00500
C
                                                                           CCECC700
C
                                                                           00800900
      INTECEN
                                                                           00600300
     . ABCEK . CTI
                     . 612 . 613
                                     . 614 . 615
                                                     . FCUN . FCON
                                                                           00001000
                     . SCADUN. SCA
     . SCNEUN . SCN
                                      . SFKDUM. SFR
                                                       · SFR
                                                              . 56
                                                                           001100
                                                                · SLK
     . 51
             . 316
                      . SIXDUM. SIX
                                      . SKCU4 . SK
                                                       . SL
                                                                           00510902
                                              . SPIDUM. SPI
                                      . SCK
                                                               . SQF
     . SNA
             . SMLLLIN. SMC . SMV
                                                                           CCEC1 30C
                                               . sve
                                                       · SVD
     . SGL
             . 34
                     . SSCN . SSIR
                                      . SVA
                                                               . 5V1
                                                                           CCE01400
                             . SAP
                                               . TORG
                                                               . SEU
     . SVM
             · SVP
                      . EVG
                                      . SAT
                                                       . SMAL
                                                                           COPCISOC
                     . NELXA . SELX
                                      . SFEM
                                             . AMEDS . SFCC
                                                                           00001000
     . >(
             . 500
                      . 121517(1)
                                                                           C0#21700
     . IINIT(1)
                                      . aD
0
                                                                           CCP21800
                                                                           COF31400
     SE AL SE
                                                                           0002000
                      . CAF (2.10) . ETIC (3.10) . ETMC (3.10) .
     . ANGC (23)
                                                                          00120800
```

. TC ZEHO. SEE SUB INOPT AND MAIN ")

C078560C

```
* FLQ (3.20) . FLE (3.3.20), FLH (3.3.20).
                                                                         00502200
     • (HAC) (23) . YMCD (3.2.11), RINIT (1) . RZIN!T(1)
                                                                         CC#02300
C
                                                                          CCE22400
     COMEN /CHEKS/
                              NETART. LRTAPE
                                                                          CC802500
C
6
                                                                          CCFC270C
C
                                                                          CCEO2800
     CUMPEN /LUGIC/ Ful. F32, FG3, FG4, FG5, INEFF, RELUCTO)
                                                                         COF02900
C
                                                                         CC603000
C
                                                                         CCE03100
     COMMEN /INTO/
                       (005) AROMA
                                                                          CCECAZOC
                                     . CT3
                                                      . CT4
     • CT1
                     . CT2
                                                                         CC80330C
                     . FLON (23)
     • 615
                                     . JCCN (13)
                                                      . LCUN (22)
                                                                      . COE03400
     . MC
                                                                      . 00803500
            (10)
                    . NE1
                                      CULM .
                                                      . NCTC
                     . NFKC
                                                      . NLCH
     . NFER
                                     . NEHC
                                                                         C0 F03600
                                     . NMCA
                     . NHO
     . ...
                                                      . NSVP
                                                                         0003700
                     . FCLN (11)
                                                      . SFA (33)
                                   . 50
. 516
     . NSVC
                                                                         C060380C
     . 56
                     . 51
                             (55)
                                                     . SL
                                                                      . 00803900
                                                     , SQF (11)
            (23) . SMA
(11) . SMV
                             (10)
                                   . SCK (11)
                                                                         ((+04000
     · SLK
     · SCL
                                      . 54
                                                      . SSCN
                                                                          CCE24100
                     . SVA
                                                      . SVE
     . 551)
                                      . SVd
                                                                         CC+24200
                     . SVM
                                                                      . (0004300
     · SVI
                                      . SVP (22)
                                                      . SVG (33)
     . SXM (3.10) . SXT
                                      . TURU (+7)
                                                                      . 0000000
                                                     . SMAL
                    . ATO
                                              (33)
                                                      . SCG
                                                                         CC804500
     · SEU
                                      . sc
                                      . SFXM (12)
                     . SFL X
                                                                         CC+C4600
                                                      . AMCDS
     . NFL Nd
                     . SCC (10)
     · SFCC
                                                                          CC#0470C
C
                                                                         00840933
                                                                         C0 6 C4 9 C C
C
     COMMEN / INTG //
                                                                          CC#C5000
                                    . SCHOUM
                                                     . SCR (9)
     • SCNEL4 . SLN (S)
                                                                      . CC+05100
    . SFKCLM
                     . SFK (5)
                                     . SIXDUM
                                                     . 51x (9)
                                                                      . (0475200
                           (5)
                    . SK
                                     . SPIDUM
                                                     • SP1
                                                            (9)
                                                                      . (0005300
     . SKOLM
     . SECCUA
                    . SAC
                             (5)
                                                                          CCE 35400
                                                                          CONOSSCO
C
                                                                          00805600
     COMMEN /FEAL/
                                                                         CO8257CC
                             (3.10) . CLM (10)
(2.11) . ETM (33)
                                                    . CGMC (3.11) .
     • CA (2.10) . CAC
• OCMC (2.11) . ETC
                                                                         CCE2580C
                                                                         CCPC5900
     . GAM
            (2.00) . "
                                      . HIP (3.10) . HMC
                                                              (3.10) . ((606000
     • FMOR (12) • PHI (2.11) • PLM
• GFC (3.33) • GL (3.22) • GLC
                                                     . OF
                             (2.11) . PLM
                                             (10)
                                                              (3.33) .
                                                                         00100400
                                                              (2.11) .
                                             (3.22) . HOME
                                                                         00596500
                                                      . THAD (33)
                                       THA
                                             (33)
                                                                         CCEDE 4CO
                    . THA. (10)
                                                              (3.3.10). 00806400
     . THAC. (10)
                                     . XOIC (3.3.00). XI
            (33) , FLA (3,20) , FLO (3,20) , FLC
     . XIC (3.3.10). MAS (10)
                                                             (3.3.10). (0806500
    • TLG (33) , FLA (3.20) , FLB (3.20) , FLC (3.20) , FLD (3.3.20), FLJ (3.3.20), CAQ (3.10) , XIU (3.3.10), FLIFC (3.10) , FLGC (3.20) , FLGC (3.20) ,
                                                                         00000000
                                                                         CC#26700
                                                                         ((+06800
     • FLC (20) . ZETA (20) . FCF (3.40) . FCK (3.3.40).
                                                                         00966833
     . TIMENJ
                                                                          CC 637200
                                                                          CCE07100
C
                                                                         C080720C
0
     COMMEN /REALZ/
                                                                         CCE27300
                            (3.10) . C3CDUM(1.3) . C8C (3.10) . C08C740C
     . Cecum (1.3) . Ce
     . X*CCL4(1.1.4) . XMC
                             (2.3.10). CON(3)
                                                                          CC PC 7500
                                                                         COP27602
     COMMON /SATELL/ DLMMY(10CC)
                                                                         CO # C 7 7 0 C
                                                                         CC#27800
C
                  (ETM(1),THADE(1)) ,(XMN(1,1),ANGD(1)) , CCEC7900
(XMN(1,3),YMCD(1,1,1)) ,(XMN(1,6),CNF(1,1)) , CCEO8000
(XMN(1,8),ETIC(1,1)) ,(XMN(1,10),ETMC(1,1)) , COEC8100
     EQUIVALENCE (ETH(1), THADE(1))
                  (XMN(1.8).ETIC(1.1))
```

```
(fL0(1.1).FLC(1.1))
                                              .(FLE(1.1.1).FLO(1.1.1)).
                  (FLH(1.1.1).FLJ(1.1.1))
                                                                            CO#06300
                  (FGI.LINIT(1))
                                              . (CA(1.1). . INIT(1))
                                                                           CCECE400
                  (CODUM(1.1).FZINIT(1))
                                              . (ABURK(1). HINIT(1))
                                                                            C0808500
                   (SCNDLW. IZINIT(I))
                                                                            CC6C8600
C
                                                                            CCBC6700
                                                                            00880833
      FF TUEN
                                                                            0000000
      ENC
                                                                            CCE09000
```

```
C
                                                                           CC 5 20 000
      SLERCUTINE THNSIV(AMT. OF .THA. JCJN. PCCN. NBUD. HULJ. INERF. AMCDUM. AMC) CO 900100
      COMPLET INITIAL TRANSFERNATION MATRICES
C
                                                                           C0500200
C
             BEOY K TO CEMPUTING FRAME COUNDINATES
                                                                           00600300
C
                                                                           C0500400
C
     ENTER SLEROUTINE WITH
                                                                           C050C500
           AMI - NUMINAL STATE THANSFURMATION MATRICES EUDY & TO BORY JCC0500600
C
C
            UF = FREE CECRDINATE VECTOR. EIGENVECTORS
           THA = RUTATION ABOUT RESPECTIVE LIGENVECTORS
C
                                                                           COS00800
     RETURN FROM SUBRULTINE . ITH
                                                                           C0900900
C
           AMC = INITIAL TRANSFORMATION MATRICES ECDY & TO COMPUTING FRACOGOIOGO
C
                                                                           CO 5 21 10 C
      IMPLICIT HEAL . BLA-H. C-2.11
                                                                           (0901200
      LOCICAL
                HULDE ID. INEMF. LFUU
                                                                           02501300
      LEGICAL
                      LAUNGE . LIANSI . LVUIV . LLQUIV . LTRAN .
                                                                           COS01400
                      LTHANY . LEATE . LXUY . LETA . LTCFQU .
                                                                           CO 501500
                       LGFDOT . LDCT
                                       . LANGLE . LSETUP . LSIMG
                                                                           C0501600
      INTECEN
                 JCCNE IIIICCNE II
                                                                           C0901700
      CIMENSICK AMT(3.3. 1).GF(3. 1).THA( 1)
                                                                           CC 501 800
      CINENSICA EMCCLM(1.1.9).ANC(3.J. 1)
                                                                           (0501900
      CINENSILA ATMP(3.3).XTM1(3.3).XTM2(3.3)
                                                                           00522000
      CIPERSICK wf1(3).271(4).272(4).273(4).274(4).472(3)
                                                                           CO 502100
      COMMEN /LDEBUG/ LAUNGE . LTHASE . LVDIV . LEGUIV . LTHAN .
                                                                          00502200
                       LIFANY . LEATE . LXCY . LETA . LTURGU .
                                                                           00522300
                       LOFDOT . LOCT . LANGLE . LOETUF . LSIMO
                                                                           C0502400
      EGUIVALENCE (LIMNSI.LEGLI
                                                                           00522500
C
                                                                           C0502600
C
      COMPLIE THAN SPORMATION MATRICES WHICH TAKE VECTURS FROM BODY JCENE COGOZPOC
0
           TH ECOY & CUCRDINATES
                                                                           03632800
C
                                                                           (0402900
      NUTE AND TAKES VECTORS BODY & TO JOON(A) IN NOMINAL STATE
                                                                           C0003000
6
      . . 1
                                                                           C05031C0
      IF ( . NUT . LEUL) 60 TO 1001
                                                                           00503200
      PRINT ZCC
                                                                           00003300
      FRINT & JC
                                                                           00603400
      CU 15 K=1.NBOD
                                                                           C0503500
      FRINT COL
                                                                           COS03600
      FRINT 202. (XMT(1.J.K).J=1.3)
                                                                           C0 90 3700
      FRINT 201. K. ( PMT(2.J.K) . J. 1.J)
                                                                           COMEDOGO
   15 FRINT 262. (XMT(3.J.K).JE1.2)
                                                                           0993900
 1991 CO 1 N = 1 - NO CD
                                                                           C0904000
      IF (LEJU) KI = K-I
                                                                          C09041C0
C
         XMI(1.J.K) - 3X3 TRANSFERMATION MATHIX DEGY K TJ JEGN(K)
                                                                           (0504200
C
         XIMP(1.J) - 3X3 TRANSFORMATION MATRIX ECDY JCCN(K) TO K
                                                                          C0 924 300
      CO 2 1=1.J
                                                                          C040400
      CC 2 del.3
                                                                          (0404500
```

```
2 xTMP((1.1) = XMT(J.1.K)
                                                                           COS34600
      IF ( . NCT . LEQU) GO TO 1002
                                                                          00904700
      PRINT 2C4
                                                                           C0924800
      FRINT 231. KI
                                                                           (0904900
      PRINT 205. K
                                                                           00505000
C
                                                                           00905100
     COMPLI FREE COCHDINATE LABEL
                                                                          00505200
C
 1002 IF (K.EJ.1) GO TO 3
                                                                           00505300
      # = # + 3 - PCCN(K-1)
                                                                           00505400
    3 M1 = M + 1
                                                                           00905500
      M2 = M + 2
                                                                           00505600
                                                                          (0905700
      CHECK RIGID EDDY OF LINEAR CSCILLATOR
C
                                                                          00535800
      IF (RELU(K) .AND .PC(N(K) .NE.J) UJ TO 4
                                                                           CC 905900
C
      LINEAR SECILLATUR OF THREE CONSTRAINED AXES, JODN(K) TO K
                                                                           CC506000
      CO 5 1=1.3
                                                                           C0536100
      CO 5 J=1.3
                                                                           00506200
    (L.1) QMTX = (A.L.1) DMK 3
                                                                           C0526300
      IF (LEGU) PRINT 206. K
                                                                          C0526400
      GO TC 1
                                                                          C0506500
    4 CUNTINUE
                                                                          00926600
      EDEY K IS A RIGID BODY WHICH IS CONNECTED TO BODY JOUNGE)
C
                                                                          00506700
         BY EITHER A UNE. THO CR THREE AXIS GINBAL
C
                                                                          COS06800
C
                                                                          (0406900
     FUT FILE VECTOR M IN COGFDINATE FRAME I JUB N
C
                                                                          00507000
      CALL VECTEN (GF(1.M).XTMF.GT1)
                                                                          00507100
      IF (LEGU) PRINT 207. 4
                                                                          00507200
C
      FORM RUTATION QUATERNICH EQUATION FRAME I SUB N INTO 1 SUB 1
                                                                          00507300
      CALL QUATUPIOTI.THA(M).ZTI)
                                                                          C05C74C0
      1F(LEGU) PRINT 208.M.(271(1).1=1.4)
                                                                          00507500
C
                                                                          C090760C
      IF (P(CA(K).NE.2) GC TO 6
                                                                          COSCITCO
C
     EDDY K CONNECTED TO BODY JCCN(K) BY A UNE AXIS GIMEAL
                                                                          C050780C
       COCRDINATE FRAME I SUB I IS BUDY & FIXED FRAME
C
                                                                          00907900
C
                                                                          CCSCBCOO
      CALL TRANSULZTI.XTMI)
                                                                          COSCRICO
      IF (LEGU) PRINT 205
                                                                          00508200
C
      FORM INITIAL THANSFORMATICA MATRIX JOJNIK) TO K
                                                                          CO 508 300
      (ALL NATPUL( XTML . XTMP . XMC(1 .1 . K) . J)
                                                                          COSCHACC
      IF (LEJU) PRINT 21C. K
                                                                          C0908500
      CO TC 1
                                                                          C06C8600
                                                                          COSCHIOC
C
    E IF (PCCN(K).NE. 1) CC TO 7
                                                                          COSCHHOO
      BCCY K CENNECTED TO BODY JCCN(K) BY A TOJ AXIS GINBAL
C
                                                                          COSCHOOL
C
      FREE VECTOR MI GIVEN IN BODY & COURDINATES, FORM HOTATION QUATERNICOSOSOCO
      CALL QUATUPE OF (1. NI) . THA (MI) . ZTZ)
                                                                          00909100
      IF (LEGU) PRINT 211. WI.WI.(272(1).1=1.4)
                                                                          F0509200
      FORM HESULTANT HOTATICA GLATERNIUN
C
                                                                          00509300
      (ALL GUTPUL (211.212.214)
                                                                          0040000
      IF (LEGU) PRINT 212. (214(1).1=1.4)
                                                                          00539500
                                                                          00909600
      CALL TRANSO( ZT4. XTM1)
      IF (LEGU) PRINT 212
                                                                          00509700
      FORM INITIAL TRANSFORMATICA MATRIX JOUNGE TO K
C
                                                                          00899800
      (ALL MATPUL(XTM1.XTMP.XMC(1.1.K).3)
                                                                          0099990
      IF (LEGU) PRINT 214. K
                                                                          CCSIDOCC
     GG TC I
                                                                          0010100
                                                                          00510200
C
     ECDY K CONNECTED TO BODY JOONIK! BY A THREE AXIS GIMBAL
                                                                          (0510300
    7 (ALL VECROS (QF(1.M2).G11.G12)
                                                                          COSLOADO
      CALL VECARMIGTES
                                                                          COS1 0500
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```
IF (LEJU) PHINT 215.M2
                                                                           COS10600
      THE COMPLNENTS OF FREE VECTOR MI FOR A THREE AXIS GIMBAL IN THE
                                                                           COS10700
C
C
        INTERMEDIATE FRAME I SUB 1 ARE IDENTIAL TO ITS COMPONENTS COMPUTCOSIO800
        WHEN SYSTEM IN NOMINAL STATE
C
                                                                           C0910900
      (ALL QUATUPE GT2.THA(MI).2T2)
      IF (LEGU) PRINT 216. MI.(272(1).1=1.4)
                                                                           COS1110C
      (ALL QUATOPIGE (1.M2), THA (M2), ZT3)
                                                                           COS11200
      IF (LEGU) PRINT 217. N2.M2.(2T3(1).1=1.4)
                                                                           CCS11300
      FORM RESULTANT QUATERNION BY SUCCESSIVE QUATERNION MULTIPLICATION COSTIAGO
      CALL GUINUL (ZTI.ZTZ.ZT4)
                                                                           COS11500
      IF (LEGUI PRINT 218
                                                                           CC 51 1600
      (ALL GUTPUL (ZT4.ZT3.ZT1)
                                                                           COS11700
      IF (LEGU) PRINT 215. (ZT1(1).1=1.4)
                                                                           (0911800
      (ALL THANSU(ZTI.XTMI)
                                                                           COS11900
      IF (LEGU) PRINT 220
                                                                           CC$12000
      FORM INITIAL TRANSFORMATION MATRIX JOJN(K) TO K
                                                                           00512100
      (ALL MATRUL(XTM1.XTMP.XMC(1.1.K).3)
                                                                           (0512200
      IF (LEGJ) PRINT 214. K
                                                                           (0512300
    1 CENTINUE
                                                                           C0912400
      IF (LEJU) PRINT 204
                                                                           00512500
C
                                                                           00912600
      ALL CENTIGUOUS BUDY TRANSFORMATION MATRICES CUMPUTED
C
                                                                           CC512700
        >MC(1,J,K) - 3x3 THANSFCHPATION MATRIX BODY JCON(K) TO BODY K ATCOS12800
      IF( . NCT . LEGU) GU TO 1000
                                                                           00912900
      FRINT 232
                                                                           CCS1 3000
      CC 20 K=1.NHOD
                                                                           COS1 3100
      FRINT 201
                                                                           00513200
                    (XMC(1.J.K).J=1.3)
                                                                           CC513300
      FRINT ZEL.
      FRINT 222. K. (XMC (2.J.K).J=1.3)
                                                                           C051 340C
   20 FRINT 221, (XMC(3.J.K).J=1.3)
                                                                           CC 51 3500
      FRINT 2C4
                                                                           00913600
C
                                                                           COS13700
C
      COMPUTE TRANSFORMATION MATRICES, COMPUTING FRAME TO BODY K
                                                                           COS1 3800
                                                                           00513900
 1000 IF (INCAF) GU TO 8
                                                                           CC514000
      IF (LEGU) PRINT 223
                                                                           C0514100
      IF (LEGU) PHINT 201
                                                                           00514200
      10 = 1
                                                                           0914300
      GO TC #
                                                                           COS14400
    6 IC = 0
                                                                           CC 91 4500
      IF (LEGUI PHINT 224
                                                                           (0514600
      IFILEGUL PHINT 201
                                                                           COS14700
    5 ICE1 = IC + 1
                                                                           C0514800
      CO 10 KKK=1CH1.NHCD
                                                                           C0914900
      R : NOUS - (KKK-ICOI)
                                                                           CC$15000
      IF (LEGU) PRINT 201
                                                                           (0515100
                                                                           COS1 5200
   12 JK = JCCN(KK)
                                                                           C0515300
      IF (JK.EG.IC) GC TC 15
                                                                           C0515400
      CO 11 1=1.3
                                                                           CC915500
      CO 11 J=1.3
                                                                           C0515600
      *TM1(1.J) = *MC(1.J.K)
                                                                           (0515700
   11 xf w 2 (1.1) = xMC(1.1.1K)
                                                                           COS15800
      (ALL MATBUL(XTM1.XTM2.XMC(1.1.K).J)
                                                                           (0515900
      IF (LEGUI PRINT 225. K.K. JK
                                                                           C0516C00
      KK = JR
                                                                           00916100
      GO TC 12
                                                                           CC$16200
   IC CONTINUE
                                                                           CC916300
      IF (LEGU) PRINT 204
                                                                           COS16400
C
                                                                           (0516500
```

```
CET COMPLTING FRAME TO BOOK I AND TO INERTIAL REFERENCE
C
                                                                          (0516600
      IF (IC. cC.1) GO TO 14
                                                                           CC516700
      CO 15 1=1.3
                                                                           CC$1680C
      CC 15 J=1.3
                                                                           C0516900
   15 xMC(1.J.C) = 3
                                                                           CC5170C0
      xMC(1.1.C) = 1
                                                                           COS17100
      xMC(2.2.C) = 1
                                                                           COS1 7200
      xMC(3.3.0) = 1
                                                                           (0517300
      IF (LEGU) PRINT 226
                                                                           COS17400
      60 TC 16
                                                                           COS17500
   14 00 17 1=1.3
                                                                           (0517600
      CO 17 J=1.3
                                                                           C0917700
   17 XMC(J.1.C) = XMC(1.J.1)
                                                                           CC 51 7800
      IF (LEGU) PRINT 227
                                                                           COS1 7900
      CC 16 1=1.3
                                                                           C0518000
      CO 1t J=1.3
                                                                           COS18100
   18 xMC(1.J.1) = 0
                                                                           00518200
      xMC(1.1.1) = 1
                                                                           C0518300
      xMC(2.2.1) = 1
                                                                           COSIHADO
      xMC(3.3.1) = 1
                                                                          00518500
                                                                           (0518600
      IF (LEGU) PRINT 228
   16 CENTINUE
                                                                           C05187C0
\epsilon
      TRANSFOSE TO GET TRANSFORMATION MATRICES BODY K TO COMPUTING FRAME(CS18900
      MHCD1=NECD + 1
                                                                          CCS1 9000
      CO 13 KAK=1.NBOD1
                                                                           00519100
      K=KKK - 1
                                                                           00519200
      (ALL TANSPS (XMC(1.1.K))
                                                                           00519300
      IF (LEGU) PRINT 225. K.K
                                                                           00519400
   12 CENTINUE
                                                                          (0519500
      IF ( . NCT . LEUL) RETURN
                                                                           0919609
      FRINT 204
                                                                           CC519700
      PRINT 233
                                                                          00819800
      CO 21 KKK=1. NHCO1
                                                                          00919900
      K = KKK-1
                                                                          CC520C00
      PRINT 201
                                                                           00105200
      FRINT 221. (XMC(1.J.K).J=1.3)
                                                                          00520200
      FRINT 222. K. (XMC(2.J.K).J=1.3)
                                                                          00520300
  21 FRINT 221. (XMC(3.J.K).J=1.J)
                                                                          CC5204C0
      PRINT 204
                                                                          00520500
 200 FORMAT ('1 SUBROLTINE TENSIV ENTERED 1.77)
                                                                          00920600
 201 FCEMAT ('
                  .,
                                                                          00520700
 202 FORMAT (12X.3015.5)
                                                                          00820800
 203 FORMAT (' XMT('. [2.") = '.3015.5)
                                                                          00920900
  204 FORMAT (3(/))
                                                                           00021000
 205 FORMAT (' XTMP = XMT(',12.') ** T ')
                                                                          00115900
 206 FORMAT (' XMC('. 12.') = XTMP ')
                                                                          00521200
 207 FORMAT (' UT1 = XTMP * GF(',[2,') ')
                                                                          00521300
 208 FORMAT ( .
                LT1 = GLATOF(GT1.THA('.12.'))'.8x.'= '.4015.5)
 209 FURMAT ( .
                x TM1 = TRANSU(ZT1) ')
                                                                          00521500
 210 FORMAT (' XMC(', 12.') = XTM1 # XTMP ')
                ZT2 = GLATOF(CF('.12.').THA('.12.'))'.5x.'= '.4015.5) CC$21700
 211 FORMAT ( .
 212 FURMAT ('
                274 = 271 * 272 '.15x.'= '.4015.5)
                                                                          00821800
 213 FORMAT ( .
                xTM1 = TRANSC(ZT4) ')
                                                                          00921900
 214 FORMAT (' XMC('.12.') = XTM1 * XTMP ')
                                                                          00055500
 215 FORMAT (' QT2 = NCRM(GF('.12,') x GT1)')
 216 FORMAT (' ZT2 = GUATOF(GT2.THA(',12.'))',8x.'= ',4015.5)
                                                                          (0922200
 217 FORMAT (' 2T3 = GLATOP(GF('.12.'),THA('.12.'))'.5x.'= '.4015.5)
218 FORMAT (' 2T4 = ZT1 * ZT2 ')
                                                                          00622300
                                                                          00622400
 215 FORMAT (' 271 = 274 + 273 '.15x.'= '.4015.5)
                                                                          00522500
```

```
22C FORMAT (' XTM1 = THANSG(ZT1) ')
                                                                          00922600
221 FCFMAT (12x. 3015.5)
                                                                          CO 522700
222 FORMAT (' XMC(',12.') = ',3015.5)
                                                                         00922800
223 FORMAT ('
               LEMPUTING FRAME FIXED IN BUDY 1 ')
                                                                          CC 52290C
224 FORMAT (' COMPUTING FRAME FIXED INERTIALLY')
                                                                          00023000
225 FORMAT (' XMC(',12,') = XMC(',12,') * XMC(',12,') ')
                                                                         CC523100
226 FORMAT (' XMC( C) = 1 ')
                                                                          C0923200
227 FORMAT (' XMC( 0) = XMC( 1)**T ') .
                                                                          00523300
22E FORMAT (' XMC( 1) = 1 ')
229 FORMAT (' XMC(',12,') = XMC(',12,')**T ')
                                                                          00923400
                                                                          C0923500
230 FORMAT (10A, TRANSFORMATION MATRICES, NOMINAL STATE BODY K TO EOOCO923600
   *Y JC(N(K) 1.//)
                                                                          C0 52 3 70 C
231 FORMAT (10x. HINGE POINT '.12./)
                                                                          00823800
232 FORMAT (10x, ' TRANSFORMATION MATRICES, TIME ZERO BUDY JCON(K) TO B(C923900
   *CDY K ')
                                                                          CC524000
233 FORMAT (10x, * TRANSFORMATION MATRICES, TIME ZERO BODY K TO COMPUTICOS24100
   ING FRAME ! ./)
                                                                          CC524200
    SE TUEN
                                                                          C0524300
    ENC
                                                                          C0524400
```

```
C
                                                                      C1 C00000
      SUERCUTINE VOIV
                                                                      C1C0C100
C
      USED TO TRANSFORM ALL VECTORS AND DYADS TO COMPUTING FRAME
                                                                      C1CC0200
C
        CEFINES FREE AND LOCKED VECTORS NOT INPUTED
                                                                      C1 CC030C
C
       SETS UP DU LOUP SETS FOR TRANVO
                                                                      C1 C00400
C
                                                                      C1C00500
C
                                                                      C1 C00600
     IMPLICIT REAL+8(A-F,U-Z,1)
                                                                      C1C00700
     LOGICAL FG1. FG2. FG3. FG4. FJ5. INERF. HOLD. LEGU. LINIT(1)
                                                                     C1C2C800
                    LTRANY . LTATE . LXDY . LETA . LTORGU .
     LOGICAL
                                                                      C1 CC0900
                                                                      C1 C01 000
                     LGFDOT . LOCT . LANGLE . LSETUP . LSIMO
                                                                      C1C21100
C
                                                                      C1C01200
C
                                                                      C1C01300
     INTECER
                                                                      C1C21400
                                                   . FCCN . PCCN . C1001500
     . ANCRK . CTI
                   , CT2 , CT3 , CT4 , CT5
     . SCNELM. SCN
                   . SCRDUM. SCH
                                  . SFKDUM, SFK . SFH . SG
                                                                     C1CC1600
                                  . SKOUM . SK
            . 516
                                                           . SLK
     • SI
                    . SIXCUM. SIX
                                                   . SL
                                                                     C1001700
                                                           . SQF
     . SHA
             . SMLDUR. SMC . SMV
                                   . SOK
                                           . SPIDUM. SPI
                                                                      C1001800
            . Sk
                   . SECN . SSIX . SVA
     * SCL
                                           . SVB . SVD . SVI
                                                                      C1001900
     . SVM
           . SYP
                   . SVQ . SXP
                                   . SXT
                                           . TORG . SMAL . SEU
                                                                      C1 C02000
                   . NFLXB . SFLX . SFXM . NMUCS . SFCC . SCC
     . 50
                                                                  . 01002100
             . SCG
                                   . 50
     · IINIT(1)
                    . IZINIT(1)
                                                                      C1002200
C
                                                                      C1002300
C
                                                                      C1002400
C
                                                                      C1 C02500
     FEAL +8
                                                                      C1022600
                   . CAF (3.10) . ETIC (3.10) . ETMC (3.10) . 01002700
     * ANGC (33)
     • FLQ (3.20) . FLE (3.3.20), FLH (3.3.20).
                                                                      C1002800
                                                  , RZINIT(1)
     . THACD (23)
                  . YMCD (3.2.11). RINIT (1)
                                                                      C1 CC2900
C
                                                                      C1 C03200
C
                                                                      C1C03100
C
                                                                      C1C03200
C
                                                                     C1C03300
     CCMMEN /LDEBUG/ LRUNGE . LTENSI . LVDIV . LEQUIV . LTRAN .
                                                                     C1 C0 34 CO
                     LIRANY , LRATE , LXUY , LETA , LTORQU .
                                                                     01003500
```

```
LOFDOT . LDCT . LANGLE . LSETJP . LSIMO
                                                                             C1C03600
C
                                                                             C1 C03700
C
                                                                              C1 C0380C
       COMMON /LUGIC/ FG1. FG2. FG3. FG4. FG5. INEMF. RBLU(10)
                                                                             C1C039C0
C
                                                                             C1 C04000
C
                                                                             C1C0410C
      CCMMEN /INTG/
                        ANDRK (200)
                                                                             C1C34200
                                        . CT3
                       . (12
      • CT1
                                                         . CT4
                                                                             C1C04300
      * C15
                       . FCUN (33)
                                        . JCCN
                                                (10)
                                                         . LCCN
                                                                  (22)
                                                                            C1C0440C
                                                                          .
      . MC
                                        · Nauo
                                                         . NCTC
              (10)
                       . NE1
                                                                            C1 C04500
                                        . NFRC
                                                         . NLUR
      * NFER
                       . NFKC
                                                                             C1 C04600
                       . NMC
                                        . NMOA
      * NMV
                                                         . NSVP
                                                                             C1 C04700
                                        . 50
                                                         . SFR
                       . FCON (11)
      . NEVC
                                                                             C1C04800
                                                                 (33)
                       . 51
                                        . SIG
                                                         · SL
      . 56
                              (55)
                                                                            C1C24900
      * SLK
                      . SMA
                                                        . SUF
              (33)
                               (10)
                                        . SCK
                                                (11)
                                                                  (11)
                                                                            C1005000
      * SCL
                      . SMV
              (11)
                                        . SR
                                                         . SSCN
                                                                             C1C25100
                                        . SVB
                       . SVA
                                                         . SVD
      . SSIX
                                                                             C1005200
      * SVI
                       . SVM
                                        . SVP
                                                (22)
                                                         . SVU
                                                                 (33)
                                                                            C1 C05300
      * SAM
              (3.10)
                      . SXT
                                        . TURU (97)
                                                        . SMAL
                                                                            C1C25400
                                        . SC
      . SEU
                       . NTQ
                                                (33)
                                                        . 506
                                                                             C1005500
                       . SFLX
     * NFL >B
                                        . SFAM
                                                (10)
                                                        . MMCDS
                                                                             C1 C05600
      • SFCC
                       . SCC
                             (10)
                                                                             C1 C05700
C
                                                                             C1 C35800
C
                                                                             C1 C05900
      CCMMCN /INTGZ/
                                                                             C1 C06000
                      . SCN
                                       . SCROUM
                                                        . SCR
      * SCNCLM
                               (5)
                                                                 (9)
                                                                            C1006100
     . SFKCLM
                      . SFK
                               (5)
                                       . SIXDUM
                                                        . SIX
                                                                 (9)
                                                                            C1006200
                      . SK
                                                        · SPI
     . SKOLP
                               (4)
                                        . SPIDUM
                                                                 (9)
                                                                          . 01006300
     . SMCCLA
                      . SMC
                               (5)
                                                                             C1 CC6400
C
                                                                             C1 C065C0
                                                                             C1C06600
                                                                             C1C06700
      CEMMEN /HEAL/
              (3.10) . CAC
(3.11) . ETC
                                                      . CCMC (3.11) . C1C06800
     . CA
                               (3.10) . CLM
                                                (10)
     . DCMC (3.11)
                                                        . FUML
                              (3.11)
                                       . ETM
                                                (33)
                                                                (2.11)
                                                                            C1 CC6900
              (3.66) . F
                                                (3.10) . HMC
                                                                 (3.13) .
      . GAM
                                       . HM
                                                                            C1 C0730C
                       . PFI
     * HNON (10)
                             (2.11)
                                       . PLM
                                                (10)
                                                        . OF
                                                                 (3.33)
                                                                            C1CC7100
                                      . 010
                                                                 (3.11) .
                                                (3,22) . RCMC
     • QFC
             (3.33)
                      . GL
                              (3,22)
                                                                            C1C07200
     * T
                                          THA
                                                (13)
                                                        . THAD
                                                                 (33)
                                                                             21007300
                      .
                      . THAW (10)
     . THACH (10)
                                                                 (3.3.10).
                                                                             C1007400
                                       , XUIC (3,3,60), XI
                                                                            C1 CC7500
     * XIC (3,3,10), XMAS (10)
                                       . XMN
                                               TMX . (EL, EE)
                                                                 (3.3.10) .
     * TLG (33) . FLA (3.20) . FLB (3.20) . FLC (3.20) . FLC (3.20) . FLD (3.3.20), FLJ (2.3.20), CAD (3.10) . XID (3.3.10). FLIRC (3.10) . FLCC (3.10) . FLCC (3.20) . FLCC (3.20) .
                                                                             C1 CC7600
                                                                             C10077CO
                                                                             C1C27800
     * FLON (20)
                      . ZETA (20)
                                      . FCF
                                               (3,3,40) . FCK
                                                                (3.40) .
                                                                            C1 CC7900
     . TIMENU
                                                                             C1 C08000
                                                                             C1C08100
                                                                             01008200
C
      CCNMIN /FEALZ/
                                                                             C1C08300
     . CECLM (1.3) . CE
                              (3.10) . CBCDUM(1.3) . CBC
                                                                (3.10) . 01098400
     . XMCCLM(1.1.9) . XMC
                              (2.3.10). CON(3)
                                                                             C1 C08500
                                                                             C1 CC#600
C
                                                                             C1 C08700
      EQUIVALENCE (ETM(1).THADE(1))
                                               . (XMN(1.1). ANGU(1))
                                                                            C1C08800
                   (XMN(1,3),YMCC(1,1,1))
                                               . (XMN(1.6).CNF(1.1))
                                               +(XMN(1+10)+ETMC(1+1)) +
                                                                            (1009000
     ٠
                   (XMN(1.8), ETIC(1.1))
     •
                   (FLB(1.1).FLG(1.1))
                                               . (FLE(1.1.1).FLD(1.1.1)).
                                                                             C1C09100
                                                                             C1C09200
                   (FLH(1.1.1).FLJ(1.1.1))
                   (FGI.LINIT(1))
                                               .(CA(1.1).AINIT(1))
                                                                             C1 C09 300
                   (CHDUM(1.1), FZINIT(1))
                                               . (AWURK(I). IINIT(I))
                                                                            C1 C09400
                   (SCNDLM, IZINIT(1))
                                                                             C1 C2950C
```

```
C1 C09600
C
      LOGICAL CTAIN
                                                                               C1 C05700
      INTECER SET(18).S(18).SS(18)
                                                                               C1 CC9800
      INTECER ST 1(10). ST2(10). ST3(10). ST4(10). SFXMN
                                                                               C1009900
      HEAL 48 TEM(3). TEM1(3.3). TEM2(3.3). TEM3(3.3)
                                                                               C1 C1 0000
      EQUIVALENCE (LVDIV.LEGU)
                                                                               C1C10100
C
                                                                               C1C10200
C
                                                                               C1 C1 0300
C
                                                                               C1C1040C
      IF (LEGUJFRINT 200
                                                                               C1C10500
C
                                                                               C1 C1 0600
      IF (INCHF) GO TO 1
                                                                               C1 C1 0700
                                                                               C1010800
      1C = 1
      IF (LEGUJFHINT 201
                                                                               C1 C1 0900
      60 TC 7
                                                                               C1 C1 1000
    1 IC = 0
                                                                               C101110C
      IFILEGUIFRINT 202
                                                                               C1C11200
    7 CENTINUE
                                                                               C1 C1 1 300
                                                                               C1011400
C
      INCLUDE FLEXIBILITY EFFECTS
                                                                               C1 C1 1500
      IF (NFLXE.EU.C) GO TO 75
                                                                               C1 C1 160C
      CALL UNPACISET. NSET. SFLX)
                                                                               C1C11700
      IF (LEGU) PRINT 231. SFLX.(SET(1).1=1.45ET)
                                                                               C1011800
      SAVE UNDEFORMED OF VECTOR AND INERTIA TENSOR DATA
C
                                                                               C1 C1 1 900
      NN = C
                                                                               C1C12C00
      CO 76 NA=1 . NSET
                                                                               C1012100
      N = SET(NSET+1-NN)
                                                                               C1012200
      IF (LEGU) PRINT 257. N
                                                                               C1 C1 2 30C
      CO 77 1=1.3
                                                                               C1 C1 2400
      CAC(I.N) = CA(I.N)
                                                                               C1 C1 2500
      CC 77 J=1.5
                                                                               C1 C1 2600
   77 >1C(1.J.N) = X1(1.J.N)
                                                                               C1 C1 2700
                                                                               C1 C1 2800
      IF (.NGT.LEGU) GU TO 10C1
      FRINT 232. N.N
                                                                               C1C12900
      FRINT 234. N.N
                                                                               C1C130C0
      FRINT 233
                                                                               C1 C1 3100
 1001 CENTINUE
                                                                               C1013200
      SFXMA = SFXM(N)
                                                                               C1C13300
      CC 7E M=1. SF XMN
                                                                               C1 C1 34 CC
      WN = WN+1
                                                                               C1 C1 3500
      (ALL VECTHN(FLA(1 .MN) .XMC(1 .1 .4) .FLAC(1 .MN))
                                                                               C1 C1 3600
      IFI.NUT.LEGUI GO TO 1002
                                                                               C1013700
      FRINT ZEE. N.MN
                                                                               C1C13800
      PRINT 246. MN. N. MN. (FLAC (1. MN) . 1=1.3)
                                                                               C1C13900
      FRINT 233
                                                                               C1 C1 40C0
 1002 CONTINUE
                                                                               C1C14100
      USE TEMPERARY LOCATIONS SO THAT
                                                                               C1C14200
      EGUIVALENCE MAY BE USED TO SAVE STORAGE
                                                                               C1 C1 4 300
C
      CC 75 I=1.3
                                                                               C1014400
      CU 75 J=1.5
                                                                               C1 C1 4500
      TENI(I.J) = FLO(I.J.MN)
                                                                               C1 C1 4 60 C
      TENZ(I.J) = FLG(J.I.MN)
                                                                               C1 C1 4 700
   75 TEN3(1.J) = FLJ(1.J.MN)
                                                                               C1 C1 4 800
      (ALL CYACU(TEMI.TEM2.FLE(1.1.MN))
                                                                               C1014900
      (ALL LYACDITEMI.TEM3.FLH(1.1.MN))
                                                                               C1 01 5000
      IF ( . NCT . LL UU) GU TC 10C3
                                                                               C1C15100
      FRINT 244.
                         (FLE(1.1.MN).1=1.3)
                                                                               C1015200
      FRINT 242.MN.MN.MN.(FLE(2.1.MN).1=1.3)
                                                                               C1015300
      FRINT 244.
                          (FLE(3.1.MN).1=1.3)
                                                                               C1015400
      FRINT 233
                                                                               C1 C15500
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FRINT 244.
                   (FLF(1,1,MN),[=1,J)
                                                                            C1C15600
      FRINT 243.MN.MN.MN.(FLF(2.1.MN).[=1.3)
                                                                            C1C15700
      FR INT 244.
                                                                            C1 015800
                        (FLF(3.1.MA), I=1.3)
                                                                            C1 01 5900
      FRINT 233
                                                                            C1 C1 6000
 1003 CONTINUE
                                                                            C1C16100
C
      CCMPLTE & VECTOR IN BODY N FIXED FRAME
                                                                            C1 C1 6200
      CALL VECRUS(CAU(1.N).FLA(1.MN).TEM)
                                                                            C1C16300
      (ALL VECSUB(FLB(1 .MN) . TEN. TEM)
                                                                            C1 C1 6400
      (ALL SELVIAMAS(N) . TEM . TEM)
                                                                            C1 C1 6500
      (ALL VECAPO(FLC(1.MN).TEA.FLJ(1.MN))
                                                                            C1 C1 6600
      (ALL VLCTHN(FLU(1.MN).XMC(1.1.N).FLUC(1.MN))
                                                                            C1C167C0
      IF(.NOT.LEGU) GO TO 1004
                                                                            C1 C1 6800
      FRINT 245. MN.MN. N.MN. N.MN. (FLQ(I.MN). [=1.3)
                                                                            C1 C1 6 900
      FRINT 233
                                                                            C1 C1 7200
      FRINT 245. MN.N.MN. (FLGC (1.MN) . 1=1.3)
                                                                            C1C17100
      FRINT 233
                                                                            C1C17200
 1004 CONTINUE
                                                                            C1217300
      CALL SCLV(THA(NFER+MN) .FLA(1.44) .TEM)
                                                                            C1017400
      CALL VECADDICALLAND. TEN. CALLIND)
                                                                            C1C17500
      (ALL SCLE(THA(NFER+MN).FLE(1.1.MN).TEM1)
                                                                            C1C17600
      CALL DYACD(XI(1.1.N) . TEM1.XI(1.1.N))
                                                                            C1 C1 770C
      IF (. NOT. LEGU) GC TC 1006
                                                                            C1C17800
                                                                            C1 C1 7900
      NECH = NELR+MN
      PRINT 24E. N.N.NFCH.MN
                                                                            CICIBOOO
      PRINT 247. N.N.NFCH.MN
                                                                            C1C18100
      FRINT 222
                                                                            C1C18200
                                                                            C1C18300
 1006 CENTINUE
   7E CONTINUE
                                                                            C1C18400
                                                                            C1C18500
      IFI.NCT.LEGUI GU TO 1007
      FRINT ZES. N
                                                                            C1018600
      PRINT 252. N.(CA(I.N). [=1.1)
                                                                            C1 C1 8700
      FRINT 233
                                                                            C101880C
      FRINT 254.
                                                                            C1018900
                   (XI(1.1.N).1=1.3)
      PRINT 255. N.(XI(2.1.N).1=1.3)
                                                                            C1 C1 9000
     FRINT 254.
                 (x1(2.1.N).1=1.3)
                                                                            C1019100
                                                                            01019200
     FRINT 233
                                                                            C1 C1 9300
 1007 CONTINUE
   76 CONTINUE
                                                                            C1 C1 9400
                                                                            C1C19500
   75 CCATINUE
C
                                                                            C1C19600
                                                                            C1019700
C
C
        CENTER OF MASS VECTORS
                                                                            C1C19800
      IF (LEQUIPRINT 204
                                                                            000001313
     DG 2 J=1.NGOD
                                                                            0.0000013
    2 CALL VELTRN (CA(1.J).XMC(1.1.J).CAC(1.J))
                                                                            01020100
      IF ( . NOT . LEUL) GO TO 1020
                                                                            0.020200
      CO 8 J=1.NBCL
                                                                            C1 C2 0 300
    E PHINT 203. J.J.J. (CAC([...).[=1.5)
                                                                            01020400
                                                                            C1020500
C
                                                                            01020600
         INERTIA TENSORS
                                                                            C1 C207CO
      FRINT 205
 1020 CALL UNPACISET . NEET . SH)
                                                                            C1 C20HC0
      CO 46 Jal . NSET
                                                                            01020900
                                                                            (1021000
      K = SET(J)
   46 (ALL TENTEN (XI(1.1.K).XFC(1.1.K).XIC(1.1.K))
                                                                            01115313
      IFI.ACT. LEGUI GO TO 1000
                                                                            C1021200
                                                                            01021300
      CO 45 JELINSET
                                                                            C1 C21400
      PRINT 233
      K=SET(J)
                                                                            C1 C2150C
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FRINT 206.
                         (X1C(1.L.K).L=1.3)
                                                                           C1C21600
      PRINT 207. K.K.K.K.K.(XIC(2.L.K).L=1.3)
                                                                           C1021700
   45 FRINT 2CE.
                         (XIC(3.L.K).L=1.3)
                                                                            (1021800
                                                                           C1 C2 1900
                                                                           01022000
1300 CONTINUE
                                                                           01022100
      GET ELEMENTS OF SVA; THAT IS, SVD MINUS ZENC CA VECTORS
                                                                           01022200
C
      IF BCCY FLEXIBLE BCTH CW VECTOR AND INERTIA TENSOR MUST BE
                                                                           01022300
C
                                                                           01022400
      TRANSFURMED EVERY STEP
C
      (ALL UNPAC(SET.NSET.SVD)
                                                                           C1 C22500
                                                                           C1C22600
      (ALL UNFAC(STI,NSI,SFLX)
                                                                            C1 C2 2 7 0 0
      IF (LEGUIFFINT 208, SVC. (SET(1) . I=1 . NSET)
                                                                           01022800
      NS = 3
      CO 51 1=1.18
                                                                           C1C22900
   51 S(I) = C
                                                                           C1 C2 3000
                                                                           C1 C2 3100
      IF (NEET.EQ. J) GO TC 5024
      DO SC J=1.NSET
                                                                            01023200
                                                                            C1023300
      * = SET(4)
      IFICTAIN(K.STI.NSII) GC TO EO
                                                                            C1C23400
                                                                           01023500
      IF (CAC(1.K).EQ.O.AND.CAC(2.K).EQ.O.AND.CAC(3.K).EQ.O) GC TO 50
   HC CONTINUE
                                                                            (1 (23600
                                                                            C1C23700
      AS = AS+1
      S(NS) = K
                                                                            C1C23800
                                                                            C1 C2 3400
   SC CUNTINUE
 5024 CENTINUE
                                                                            C1 C24000
                                                                            C1C2410C
      CALL CUMFAC(S.NS.SVA)
      IF (LEGU) PHINT 241. SVA. (S(I). I=1.NS)
                                                                           C1C24200
      CO 47 I=1.18
                                                                           C1C2430C
                                                                            C1C24400
   47 5(1) = C
      (ALL UNPAC(SS.NS.SVD)
                                                                           C1C24500
      CALL UNFACISET . NSET . SH)
                                                                           20045212
                                                                           C1C24700
            J=1.N200
                                                                           01024800
      CO 46
      IF (.NUT. (CTAIN (J. SET. NSET) . AND . CTAIN (J. SS. NS))) GU TU 46
                                                                            C1 C24400
   81 CONTINUE
                                                                           C1025000
                                                                            01025100
      K = K+1
      SIK) = 4
                                                                            C102520C
                                                                            C1 C2 5300
   44 CENTINUE
      CALL CEMPACIS.K.SVI)
                                                                           C102540C
      IF (LEGU) FRINT 204. SVI. (5(1).1=1.K)
                                                                           (1025500
     CU ON SVI ELEMENTS IN THANVE TU GET ALC
                                                                           C1 C25600
C
                                                                           C1 C25700
                                                                           01025800
        FINGE VECTORS
C
      IF (LEUU) PRINT 210
                                                                           C1 C25900
                                                                            01026300
      DO 4 J=1.18
    4 5(3) = 6
                                                                            01026100
                                                                           01026200
      CALL UNPACISET . NSET . SVD)
                                                                           001693010
      K = C
      CO 5 J=1.NdUD
                                                                           C1026400
      JJ = JCCK(J)
                                                                            01026500
      CALL VECTEN (CB(1.J).XMC(1.1.JJ).CBC(1.J))
                                                                           C1 C26600
                                                                           01026700
      IF (LEGU) FRINT 211. J.JJ. .. (CA.([.J).[=1.5)
      IF(CEC(1.J).EG.O.AND.CEC(2.J).EG.J.AND.CUC(3.J).EG.D) GU TO 5
                                                                           0.0892010
                                                                            C1 C26900
      IF ( . NOT . CTAIN( JJ . SET . N SETIL GU TU 3
      R = K+1
                                                                            C1 C2 7 COO
      S(K) = J
    5 CCATINUE
                                                                            01027200
     (H(1) ALONG WITH CPC(1) BUST BE COMPUTED AT EACH INTEGRATION STEP. C1027300
(
      PLT I IN SVB
                                                                            C1 C2 74 CC
                                                                            01027500
      . . . . .
```

```
S(K) = 1
                                                                            C1C2760C
    E CALL CEMPACISINISVE!
                                                                            C1 C27700
      IF (LEGU) FRINT 212. SVB. (5(1).1=1.K)
                                                                            C1 C278CC
       DE CN SUB ELEMENTS IN TRANCE
                                                                            C1 C2 7900
C
C
                                                                            C1 C2 B000
       NOTE CEC(1.0) IS COMPOSITE CENTER OF MASS, MUST BE CALCULATED
C
                                                                            C1C28100
C
C
        FREE AND LUCKED COUFCINATE VECTORS
                                                                            (1 028300
      IF (LEGU) FRINT 213
                                                                            C1 C2840C
      . . 1
                                                                            C1 028500
      L = 1
                                                                            01028600
      CU 9 K=1.NBUD
                                                                            C1 C287CO
      IF (K.EQ. 1) GJ TO 10
                                                                            C1 C28800
      A = A+3-FCON(K-1)
                                                                            C1028900
      L = L+PCCN(K-1)
                                                                            00099313
   10 M1 = M+1
                                                                            C1C2910C
      N2 = N+2
                                                                            C102920C
      L1 = L+1
                                                                            01029300
      12 = 1+2
                                                                            C1 C2940C
      IGCTC = FCUN(K) + 1
                                                                            01029500
      CO TC(11.12.13.14).160TO
                                                                            C1 C2960C
C
                                                                            C1 C29700
        THEEL CEGNEES OF FREEDEM
0
                                                                            C1 C24HOC
   11 CALL VECTEN (GF(1.M).XMC(1.1.FCON(M)).JFC(1.M))
                                                                           C1 C2 440C
                                                                           C1 C3000C
      CALL VECTEN (GF(1.M2).XMC(1.1.FCON(M2)).QFC(1.M2))
      IF (LEGUJENINT 214. M.FCCN(M).4
                                                                            C1C30100
      IF (LEGUIFHINT 214, MZ.FCCN(MZ),MC
                                                                           C1 C30200
      IF (FCCN(MI ). LT.O) GC TC 15
                                                                           C1 C30 300
      (ALL VECKOS (GF(1.M2).GF(1.M).JF(1.M1))
                                                                            C1 C304CC
      IF (LEGU)PHINT 230. MI.HZ.M
                                                                            C1 C10500
      CALL VECTAN (OF(1.M1).XMC(1.1.FCUN(M1)).JFC(1.M1))
                                                                           C1 C3060C
      IF (LEGU) FRINT 214. MI.FC(N(NI).MI
                                                                           C1 C3070C
      CO TC .
                                                                           CICIOHOC
   15 (ALL VECHUS (GFC(1.MZ).UFC(1.M ).UFC(1.MI))
                                                                            C1 C3090C
      CALL VECNER (OFC(1.MI))
                                                                            C1 C 31 000
      10 45 1=1.3
                                                                           C1C31100
   45 GF([.M1) = 0
                                                                            0.0215313
      IF (LEGUJERINT ale. MI. M2. M
                                                                            C1 C3 1 300
      co to .
                                                                            C1 C31 400
                                                                           C1C3150C
C
        THE DEGREES OF FREEDEM
                                                                           C1 C3160C
   12 CALL VECTHN (GF(1.M).XMC(1.1.FCJN(M)).GFC(1.M))
                                                                           C1 C31 700
                                                                            C1C31800
      CALL VECTHO (UF(1.MI).XMC(1.1.FCUN(MI)).UFC(1:MI))
                                                                           C1 C31 90C
      IF (LEJUJFRINT 214. M. FCCN(A). M
      IFILEGUIFHINT 214. MI. FCCN(MI). MI
                                                                           C1 C320C0
                                                                           C1C321C0
      IF (LCUNILIALT.D) GL TO IC
      CALL VECTOS (GF(1.M).OF(1.M1).JL(1.L1)
                                                                            C1C3220C
      IFILEGUIFRINT 237. L.M.MI
                                                                           C1 C32300
      CALL VECTRA (GL(1.L). XMC(1.1.LCJN(L)).GLC(1.L))
                                                                           C1032400
      IFILEGUIFMINT 217. L. LCINILI. L
                                                                           C1 C32500
                                                                           C1C3260C
      CO TC "
                                                                           C1 C32 70C
   16 CALL VLCFUS (OFC(1:M1:GFC(1:M1):QLC(1:L1)
      CALL VECNEM (ULC(1.L))
                                                                           01032800
      L. 1=1 25 63
                                                                            C1C32900
                                                                           C1011000
   25 GL(1.L) = 3
      IF (LEGUIFAINT 235. L.M.MI
                                                                           C1C33100
                                                                           C1C33200
     CG TL V
                                                                           C1033400
                                                                           CICIJAOC
       CHE DECREE OF FREEDEM
                                                                           C1 C 1 150C
   13 CALL VECTOR (OF(1.P), XMC(1.1.FCUN(4)). UFC(1.M))
```

```
CALL VECTAN (QL(1.L).XPC(1.1.LCON(L)).ULC(1.L))
                                                                             C1C33600
       IF (LEGU)PHINT 214. M.FCCN(M).M
                                                                             C1 C33700
       IF (LEGU)FHINT 217. L.LCCN(L).L
                                                                             C1033800
       IF (RELO(K)) GO TO 17
                                                                             01033900
       CALL VECFOS (OF(1.M).GL(1.L).QL(1.L1))
                                                                              01 (34000
       IF (LEQUIPHINT 238 . LI.W.L
                                                                             CIC341CC
       (ALL VECTRN (QL(1.L1).XMC(1.1.LCUN(L1)).QLC(1.L1))
                                                                             C1034200
       IF (LEGU) FRINT 217. LI.LCCN(LI).LI
                                                                             C10343C0
       CO TC 9
                                                                             C1C34400
   17 (ALL TANSPS (XMT(1.1.K))
                                                                             C1 C34500
       CALL VECTRN (QF(1.P1.XMT(1.1.K).TEN)
                                                                             01 (34600
       (ALL TANSPS (XMT(1.1.K))
                                                                             C1 C34 700
       (ALL VECTOS (TEN.GL(1.L).GL(1.L1))
                                                                             C1 C34800
       IF (LEGUIFRINT 239. LI.K.A.L
                                                                             C1 C34900
       CALL VECTEN (GL(1.L1).XMC(1.1.LCGN(L1)).JLC(1.L1))
                                                                             C1C35C00
       IF (LEGU) FRINT 217. LI.LCCM(LI).LI
                                                                             C1C35100
       CO TC 9
                                                                             C1C35200
C
                                                                             C1035300
      PCCN(K) = 3 ZERO CEGHEES OF FREEDOM
                                                                             C1C35400
   14 CALL VECKUS (GL(1.L).QL(1.L1).QL(1.L2))
                                                                             C1 C35500
       IF (LEGL)PRINT 217. L.LCCM(L).L
                                                                             C1 C35600
       IF (LEGUIFHINT 217. LI.LCCN(LI).LI
                                                                             C1 C357C0
       IF (LEGU)FRINT 240. LZ.L.LI
                                                                             C1C35800
       IF (LEGU)FRINT 217. LZ.LCCM(LZ).LZ
                                                                             C1 C35 900
      CO 18 11=1.3
                                                                             C1 C3 6000
       1 = 11 - 1
                                                                             C1C36100
   16 (ALL VECTAN (QL(1,L+1),X+C(1,1,LCON(L+1)),QLC(1,L+1))
                                                                             (1(36200
C
                                                                             C1 C36300
    S CONTINUE
                                                                             C1C36400
C
                                                                             01036500
C
          AT INEHTIAL CRIGIN
                                                                             C1 C36600
       . = W+3-FCON(NBOD)
                                                                             C1C367C0
      L = L.PCCN(NBOD)
                                                                             C1 C36800
      CO 15 1=1.3
                                                                             01036900
      M92 = M+2
                                                                             C1037000
      CO 25 J= P . MB 2
                                                                             01037100
   2C GF(1.J) = 3
                                                                             C1C37200
      L82 : L42
                                                                             C1 C37300
      CO 21 J=L.L02
                                                                             C1037400
   21 (1(1)) = 0
                                                                             C1C37500
   15 CONTINUE
                                                                             C1 C37600
       IF (LEGUINO = 0
                                                                             C1 C37700
                                                                             C1C37800
C
       IGCTC = FCCN(NEOD+1)+1
                                                                             C1 C37900
      GO TC (22.23.24.25).1GCTC
                                                                             C1 C38000
                                                                             C1C38100
C
        THREE CEGHEES OF FREEDOM
                                                                             C1C3H200
   22 M1 = M+1
                                                                             01038300
      #2 = M+2
                                                                             CICIRADO
      FCCN(M) = 0
                                                                             C1C38500
      FCCN(MI) = 0
                                                                             CICSBEOO
      FCCN(M2) = 0
                                                                             C1C38700
      GF(1.W) = 1
                                                                             C1 C38800
      GF (2.M1) = 1
                                                                             C1C38900
      CF (3.M2) = 1
                                                                             C1 C39000
       IF (1 ( .= 0.0) GO TO 26
                                                                             C1C39100
      CO 27 11=1.3
                                                                             01039200
       1 = 11-1
                                                                             C1 C39 300
       IF (LEGJIJM = M+I
                                                                             C1 C39400
      IF (LECU) FRINT 214. JN. NO.JM
                                                                             01 (39500
```

```
27 CALL VECTRN (QF(1.P+1).XPC(1.1.3).QFC(1.M+1))
                                                                                C1 C39600
       60 10 26
                                                                                01 039700
                                                                                0.089600
C
         THE DEGREES OF FREEDEM
                                                                                C1 C3990C
   23 M1 = M+1
                                                                                C1 C4 0000
       FCCN(M) = 0
                                                                                C1C40100
       FCCN(MI) = 0
                                                                                01040200
       LCCN(L) = 0
                                                                                C1 C40 300
       CF (1.M) = 1
                                                                                C1 C4 0 4 0 0
       CF (2.M1) = 1
                                                                                C1 C40500
       GL (3.L) = 1
                                                                                C1C40600
       IF (I (.EG.3) GO TO 26
                                                                                C1C40700
       IF (LEQUIFRINT 214. M.MC. .
                                                                                C1 C4 0800
       IF (LEGUIFRINT 214. MI.MO.MI
                                                                                C1 C4090C
       IF (LEGU)PRINT 217. L.MC.L
                                                                                C1 C4 1 000
       CALL VECTRN (QF(1.)).XMC(1.1.0).UFC(1.M))
                                                                                C1 C41100
       CALL VECTRN (QF(1.P1).XMC(1.1.3).QFC(1.M1))
                                                                                C1041200
       CALL VECTAN (GL(1.L).XMC(1.1.0).GLC(1.L))
                                                                                C1 C41 300
       60 TC 26
                                                                                C1C+1400
                                                                                C1C41500
        CHE DEGREE OF FREEDOM
                                                                                C1 C4 1 600
   24 L1 = L+1
                                                                                C1C41700
       FCCN(M) = 0
                                                                                C1 C4 1800
      LCCN(L) = 0
                                                                                C1C41900
                                                                                C1 C42000
       LCCN(LI) = 0
       CF (1 .M) = 1
                                                                                01042100
       CL (2.L) = 1
                                                                                C1C42200
                                                                                C1042300
       GL (3.L1) = 1
                                                                                C1C42400
       IF (IC.LG.0) GO TO 26
                                                                                C1 C42500
       IF (LEGUIFRINT 214. M.PC.P
       IF (LEGUIPRINT 217. L.MC.L
                                                                                C1 C4 2600
       IF (LEGU) PRINT 217. LI.MO.LI
                                                                                01042700
       (ALL VECTHN (QF(1.M).XMC(1.1.3).UFC(1.M))
                                                                                01042800
       CALL V=CIRN (GL(1.L) . KMC(1.1.0) . GLC(1.L))
                                                                                0.0024010
      (ALL VECTHN (GL(1.L1).XMC(1.1.)).JLC(1.L1))
                                                                                C1C43000
                                                                                C1 C4 11 00
      GO TC 26
                                                                                C1C43200
C
                                                                                C1 C4 3 300
        ZERC DEGREES OF PREECC.
   25 L1 = L+1
                                                                                C1C4340C
                                                                                C1 C4 3500
      L2 = L+2
                                                                                C1 C4 3600
      LCCN(L) = 3
                                                                                C1 C4 3700
      LCCN(LI) = 0
      LCCN(LZ) = 0
                                                                                C1043800
      GL (1 .L) = 1
                                                                                C1 C4 390C
                                                                                C1044000
      GL (2.L1) = 1
      GL (3.Le) = 1
                                                                                C1044130
                                                                                01044200
       # (1 C. E G. 0) GC TO 26
      CO 26 11:1.3
                                                                                C104430C
                                                                               C1C4440C
       1 = 11-1
                                                                                C1 C44500
       IFILEGUIJL = L+1
                                                                               (1 (44600
       IFILEGUIFRINT 217. JL. MC.JL
   28 CALL VLCTRN (GL(1.L+1).X+C(1.1.0).GLC(1.L+1))
                                                                                C1 C4 4 7 0 C
                                                                               108440C
      60 TC 26
                                                                                20644313
C
                                                                                C1045000
   26 CCATINUE
                                                                               C1C45100
       IF (1C.NE.C) GO TO 1025
      CO 30 1=1.3
                                                                               C1 C45200
                                                                                C1045300
      *85= ** Z
                                                                                C1 C4540C
      CO 3: J=W.Md2
                                                                               C1 C45500
   21 CFC(1.J) = JF(1.J)
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```
L02=L+2
                                                                               C1 C45600
      CO 3: J=L.LB2
                                                                              C1 C45700
   22 CLC(1.J) = UL(1.J)
                                                                               C1 C45800
   3C CONTINUE
                                                                               C1 C4 5900
 1925 CENTINUE
                                                                               C1046000
      IF (.MCT. LEGU) GU TO ICIE
                                                                               C1C46100
      FRINT 221
                                                                               C1 C46200
      CC 6C J=1.NFER
                                                                              C1 C46300
   6C FRINT 222. J.(QF(1.J).1=1.2).J.(QFC(1.J).1=1.3)
                                                                              C1C46400
      FRINT 421
                                                                              C1046500
      IF (NLCR.EQ.O)GC TC 1015
                                                                              C1 C46600
      CO 61 J=1.NLOR
                                                                              C1 C4 6700
   61 PRINT 222. J.(QL(1.J).1=1.2).J.(QLC(1.J).1=1.3)
                                                                              C1 C46800
      FRINT 221
                                                                              C1 C46900
                                                                              C1 C4 7000
C
      CYCLE THROUGH FREE VECTORS PICK OUT ONES TO BE TRANSFORMED IN TRANCICATION
                                                                              C1047200
 1015 CO 3: Jel.NFER
   33 SVC( +) = 0
                                                                               C1 C4 7300
                                                                              C1 C4 7400
      . . .
      CC 34 P=1.NFER
                                                                              C1C4 7500
      IS FREE VECTOR M FIXED IMERTIALLY
                                                                              C1 C47600
      IF (FCCN(F)) 35.36.27
                                                                              C1 C47700
   36 IF(10.00.0) GO TO 34
                                                                              C1 C4 780C
   35 K . K+1
                                                                              C1047900
      SVC(K) # M
                                                                              C1 C48000
      CC TC 34
                                                                              C1C48100
       ELEPENTS OF SVD IN SET(J)
                                                                              C1 C48200
   37 IF ICTAIN (FOON (H) . SET . NSET 1) GO TO 35
                                                                              C1 C4#300
   34 CUNTINUE
                                                                              C1C48400
      ASVG . K
                                                                              CICAMSOO
      IF (. NOT . LEGUI GU TO 1001
                                                                              C1 04 8600
      IF INEVA.EQ. DIGC TC 5716
                                                                              CICAMTOC
      CO 44 Islansva
                                                                              C1048800
   4 FRINT 224. 1.5 vg(1)
                                                                              C104890C
      PRINT 221
                                                                              C1 C49000
                                                                              C1049130
     CYCLE THROUGH LOCKED VECTORS PICK OUT ONES TO BE THANSPORMED IN TRO1049200
5716 IF (NLJH.EG.0 )GO TO 5917
                                                                              C1 C4 93 CO
1005 CO 36 Jel. NLUH
                                                                              C1 C49400
   26 SVF(J) = 0
                                                                              01 049500
SOLT CONTINUE
                                                                              C1 C49600
      . . .
                                                                              C1 C49700
      IF (NLUA . EQ. 2) GO TC 5025
                                                                              C1 C4 9800
      CO 35 L=1.NLOH
                                                                              C1 C4 9900
     IS CENSTRAINT TORQUE AECLT CLELL CCAPUTED
                                                                              C1 C50000
      IF (. NOT . CTAIN(L. SLK. NCTC)) GC TO JY
                                                                              C1050100
      IF (LCC-4(L)) 40.41.42
                                                                              C1050200
   41 IF (1C.EG.3) GO TU 39
                                                                              C1 C5 0 300
   40 . . . . .
                                                                              C1 C50400
      SVF(K) = L
                                                                              C1 C5 0 5 0 0
      CC TC 39
                                                                              C1050600
      ELEBERTS UF SVO IN SETES
                                                                              C1 C50700
   42 IF (CTAIN(LCUN(L).SET.NSET)) SJ TU 40
                                                                              CICSORDO
   35 CONTINUE
                                                                              C1 C53900
SOZE CUNTINUE
                                                                              C1 C5 1000
      ASVP . K
                                                                              C1051100
      IF (.ACT. LEUU) GO TO 101C
                                                                              01051200
      IF (NEVP.EU. DIGO TC 101C
                                                                              (1051300
      CO 65 1=1.NSVP
                                                                              C1 C51 400
   65 FHINT 221. 1.5VP(1)
                                                                              C1 C51500
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C1051600
      ZERO ALL ARKAY ELEMENTS OF GAM STONED UPPER THIANGULAR
                                                                               C1C51700
C
 1010 CO 5: K=1.NBOD
                                                                               C1C51800
      IF (LEGU ) FHINT 233
                                                                               C1 C51 900
                                                                               C1 C5 2000
      CO SE LEK . NBUD
      KL = KTC(NB1 .K-1 .L)
                                                                               C1C52100
      BUT IN LOGIC TO AVOID CLOBERING CODE JRDS STURED BY EQUIV.
                                                                               C1052200
      IF (KL.LG.I) GO TO 52
                                                                               C1052300
      IF (LEGUINI = K-1
                                                                               01052400
      IF (LEGUIFRINT 21d.KI.L.KL
                                                                               C1 C5250C
      CO 52 1=1.3
                                                                               C1C52600
      GAP( 1.KL) = 7.00
                                                                               01052700
   52 CONTINUE
                                                                               C1 C52800
                                                                               01052900
      ZERC ALL ANNAY ELEMENTS OF MOIC STONED LUBER THIANGULAR
C
                                                                               C1 C5 3000
      CO 53 K=1.NO1
                                                                               C1 C5 31 00
      IF ILEGUIFRINT 233
                                                                               C1 (53200
      CC 52 1=K.NET
                                                                               01053300
      IK = KTIINDI.I.K)
                                                                               C1C5 3400
      IF (LEGUIFHINT 215. I.K.IK
                                                                               C1 (53500
      CO 53 *=1.3
                                                                               C1 C5 3600
                                                                               C1C53700
      CO 53 A=1.3
   53 ADIC (M.N.IK) = 0.00
                                                                               CICESHOC
      IF (LEGUIFRINT 221
                                                                               01053500
                                                                               C1054000
C
C
                                                                               C1C54100
                                                                               C1 C54200
C
        FIRST FASS THROUGH. FIND THE UNION OF ALL LAUGES IN THE
                                                                               C1054300
         SETS SIX(K) .K = C . . . . NECC-1 AND THE SETS SCN(K) .K = 0 . . . . . NOUC-1
                                                                              C1C54400
      CO 55 141.NdOD
                                                                               C1C5450C
      ST2(1) = C
                                                                               C1 C54690
                                                                               01054700
   55 STACL) . 0
      CO SE JUJEI. NOUD
                                                                               C1 C54 HOO
                                                                               C1 C54900
      1-666=6
                                                                               C1 (5500C
      CALL UNFACISTIONSTIOSIXIJI)
      CALL UNPACISTE . NST2 . SCALUIT
                                                                               C1 (5510C
      IF INSTITEO. 0 160 TC 5018
                                                                               C1C55200
      20 57 1=1.NST1
                                                                               C1 C55 300
                                                                               C1055400
   67 ST1(ST1(1)) = 1
 5018 IF (NST2.EQ. 01GD TC 5019
                                                                               C1 055500
      CU SE I=1.NST2
                                                                               C1 (55600
   56 ST4(ST2(1)) = 1
                                                                               C1 C55700
 SOIS CONTINUL
                                                                               CICSSECC
   SE CONTINUE
                                                                               C1 C55900
                                                                               01056000
      NST1 # 0
      NS12 = 0
                                                                               C1C50100
                                                                               C1056200
      £0 59 J=1.NoCD
                                                                               C1 C50 300
      IF (STJ(J).EU.O) GC TO EZ
                                                                               C1C56400
      ASTI = ASTI +1
                                                                               C1 (56500
      STICASTID = J
                                                                               C1 (50600
   62 IF (514(J).Eu.O) GC TO 54
                                                                               C1 C56 700
      A512 = AST2 +1
                                                                               C1 C5680C
      L = (stenist)
   56 CCATINUE
                                                                               C1 (5690C
                                                                               01057000
      CALL COMPACESTI . NETI . SSIXI
                                                                               01057100
      CALL CCHPACISTE.NSTE.SSCAI
                                                                              C1057200
      IF (LEQUIPEINT 219. SSIX. (STICL) . 1=1.NoT1)
      IF (LEQUIPHINT &23. SSCA. (STE(1). 1=1.NaT2)
                                                                               C1 C5 7300
                                                                               C1 C5 7400
C
                                                                               C1057500
C
```

```
.
                                                                               C1C57600
      CO 63 M=1.NBUD
                                                                               01057700
   62 SGK(K) = al(K)
                                                                               C1C57800
      CALL UNPACISTIONSTIOSKOLDI
                                                                               C1C57900
      ASTI = ASTI +1
                                                                               C1 (58000
      STICASTI) = NOI
                                                                               C1C5#100
      CALL CUMPACISTI.NETI.SCK(NBII)
                                                                               C1C58200
C
                                                                               C1 C58300
C
      COMPLIE ACTUAL PUSITION OF FOINT MASSES
                                                                               C1 (58400
C
            NUMINAL CACCES + DISPLACED THA (MI + OFC(P)
                                                                               C1 C58500
      CALL UNPACISET . NSET . SLI
                                                                               CICSHEDO
      IF (NSET . 10.0160 TC 5026
                                                                               C1 C5 H 7 CC
      CO 7C KR-1. NSET
                                                                               C1 C58600
      A = SET(KK)
                                                                               C1 C58400
      MESCF(K)
                                                                               C1 C59000
      APPEDD+2-PCuh(K)
                                                                               C1 C59100
      CO 7: MEDW.MAN
                                                                               C1 C59200
      CO 71 1=1.3
                                                                               01059300
   71 CAC(I.K) = CAC(I.K) + THA(M)+JFC(I.M)
                                                                               C1 C59400
      IF (LEGUIFHINT 220 . K.K.M.M
                                                                               C1 (59500
   72 CCATINUE
                                                                               C1 C59630
   7C CONTINUE
                                                                               C1 C5 9 700
 SIZE CONTINUE
                                                                               C1 C59800
C
                                                                               C1 C59900
C
                                                                               01000000
        ANGULAR MUMENTUN WHEEL
C
                                                                               C1 C601 00
      IFILEGUIFNINT 226
                                                                               01060200
      IF (N.C. EG. 0) GU TO 5020
                                                                               C1063300
      CC 43 J41.NMC
                                                                               C1C60400
   43 5(3) = 2
                                                                               C1 C6 05 00
 SOZE CENTINUE
                                                                               20909313
      R = C
                                                                               C1 C607CC
      IF (NAC.EC.D) GJ TC 5027
                                                                               C100000C
      CO 44 JOI .NMC
                                                                               C1C60900
         HMILLIJI = CEMPERENTS OF SPIN ANIS
c
                                                                               00010010
         HECH(J) & RELATIVE MOMENTUM I.V. Adjut SPIN AXIS
                                                                               C1 C61100
      CALL VECTEN (HM(1.J).XPC(1.1.4J(J)).H4C(1.J))
                                                                               01061200
        FMC(1.J) = SFIN AXIS CEMPCHENTS IN COMPUTING FHAME
                                                                               C1061300
      IF (LEJUJFAINT 227. J.MC(.).J
                                                                               C1 C61+00
      .J = W_[J]
                                                                               C1 C61 500
       ELEVENTS OF SVG IN SETELI
                                                                               00010010
      IF ( . NOT . CTAIN( JJ . SET . NEE 11) GJ TU ..
                                                                               C1 C6 17 CO
      . . . . .
                                                                               C1 06 1 80 0
      5(K) . J
                                                                               C1 C6 1 900
   44 CONTINUE
                                                                               01062000
 SO27 CONTINUE
                                                                               00154313
      CALL CLMPACISIKISANI
                                                                               20526213
      IF (LEGUIFAINT 224. SVM. (S(1).1=1.A)
                                                                               01062300
          LSE SUM ELEMENTS IN TRANSPORTUGET HMC
                                                                               C1 C6 2400
      IF (LEGUIFMINT 233
                                                                               C1 C62500
      IF ( . ACT . LEUU) HE TLAN
                                                                               C1 C62600
      IF (A.C. EG. D) RETURN
                                                                               C1 C62700
      CC 66 JELINED
                                                                               $106280C
   DE FHINT 220. J. (FMC(1.J).1:1.2)
                                                                               C1 C62900
      FRINT 233
                                                                               0000 40 10
  200 FORMAT ("1 SUBBOLTINE VOIV ENTERED " . 2 (/1)
                                                                               00160013
  201 FORMAT ( . COMPUTING FRAME IS SUDY 1 ...)
                                                                               005160110
                                                                               C1 C63330
  503 FCEMAT (' CAC('.12.') = XMC('.12.') . CA('.12.') = '.3015.5)
                                                                               C1 C6 1400
  234 FC#MAT (2(/).
                                                                               C1 C6 3500
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CENTER CF MASS VECTORS 1./)
                                                                                        21063600
2CE FORMAT (2(/).
                                                                                         C1 C63700
                                     INERTIA TENSORS './)
                                                                                        C1C63800
206 FORMAT (44x. 3015.5)
207 FORMAT (' XIC('.12,') = XMC('.12,') * X1(',12,') * XMC(',12,')**TC1064000
   . = 1.3015.51
                                                                                         C1064130
208 FORMAT (/.' SVD = '.Zb.' ELEMENTS OF SET ARE '.1015./)
209 FORMAT (/.' SVI = '.Ze.' ELEMENTS OF SET ARE '.1015./)
                                                                                        C1 C64 100
210 FORMAT (2(/).
                                      FINGE VECTORS 1./)
                                                                                        C1 C6 4500
211 FORMAT (' COC('.12.') = XMC('.12.') + CO('.12.') = '.3D15.5)
                                                                                        (1 064600
212 FORMAT ( /. ' SVE = '.28.' ELEMENTS OF SET ARE '.1015./)
                                                                                        C1 C64 700
213 FORMAT (2(/).
                                                                                        C1 C64800
                            FREE AND LUCKED CUUNCINATE VECTORS 1./1
                                                                                        C1 C64900
214 FORMAT (' QFC('.12.') = XMC('.12.') = QF('.12.') ')
215 FORMAT (' XDIC('.12.'.',12.') = XCIC('.12.') = 0 ')
21c FORMAT (' QFC('.12.') = NURM(QFC('.12.') X QFC('.12.')) ')
                                                                                        C1 C65C00
                                                                                       C1C65200
217 FORMAT (E5x.' QLC(',12,') = XMC(',12,') + GL(',12,') ')
218 FORMAT (' GAM('. 12.'.'. 12.') = GAM('. 12.') = 0 ')
                                                                                        C1 C65400
219 FORMAT (EX.' SSIX = '.ZE.' UNIJN OF ALL LABELS IN THE SETS SIX(K)C1C65500
   *ARE '.1015)
                                                                                        01065600
22C FORMAT (EX. SSCh = '.ZE.' UNION OF ALL LABELS IN THE SETS SCN(K)CICES700
   . ARE '.1C15)
                                                                                         C1 C65800
221 FORMAT (3(/))
                                                                                         C1 065900
222 FORMAT (' QF('.12.") = '.3015.5.5x.' QFC('.12.') = '.3015.5)
223 FORMAT (' QL('.12.') = '.3015.5.5x.' QLC('.12.') = '.3015.5)
                                                                                       01066000
                                                                                       001000110
224 FORMAT ('
                  >VQ('.12.') = '.15)
225 FURMAT (' SVP('. 12.') = '. 15)
                                                                                        C1 C66300
226 FORMAT (3(/).25x. MCMENTUM WHEELS 1./)
                                                                                        C1 C66400
227 FORMAT (' HMC(',[2,') = XMC(',[2,') + HM(',[2,') ')
                                                                                        C1 C66500
228 FORMAT (' LAC(',12.') = CAC(',12.') + THA(',12.')*UFC(',12.') = 'C1C66600
    · .3015 .5)
229 FORMAT (2(/).
' SVM = '.Z8.' ELEMENT: OF SET ARE '.1015)
                                                                                        C1C66800
230 FCRMAT (" HMC(".12.") = ".3015.5)
                                                                                        C1 C6 7000
231 FORMAT (/. * SFLX = 1.28. * ELEMENTS OF SET ARE 1.1015./)
                                                                                        C1 C6 7100
232 FORMAT (39x.' CAC('.12.') = CA('.12.') ')
                                                                                         01067200
233 FORMAT ( ' ')
                                                                                         C1 C67300
234 FORMAT (39x.' XIC('.12.') = XI('.12.') ')
                                                                                        C1 C6 7400
235 FURMAT (E5x.' GLC('.[2.') = NJRM(GFC('.[2.') x GFC('.[2.')) ') C1C67500
236 FORMAT (35x.' GF('.[2.') = UF('.[2.'] x GF('.[2.']) ')
236 FORMAT (35X.' GF('.12.') = GF('.12.') x GF('.12.') ') C1067600
237 FORMAT (35X.' GL('.12.') = GF('.12.') x GF('.12.') ') C1067700
238 FORMAT (25X.' GL('.12.') = GF('.12.') x GL('.12.') ') C1067800
239 FORMAT (35X.' GL('.12.') = XMT('.12.')**I * GF('.12.') x GL('.10067900)
   .2. 1) 1)
                                                                                         C1064000
240 FORMAT (25x.' GL('.12.') = GL('.12.') x GL('.12.') ')
241 FORMAT (/,' SVA = '.28.' ELEMENTS OF SET ARE '.1015./)
                                                                                        C1 C6 H2 00
242 FORMAT (' FLE(',12,') = FLC(',12,') + FLC(',12,')**T =',27x.3012.01068300
                                                                                         C1 C68400
243 FORMAT (* FLH(*.12.*) = FLD(*.12.*) + FLJ(*.12.*) = *.30x.3012.5) C1C68500
244 FORMAT (61x. JD12.5)
245 FORMAT ( * FLU(', 12, ') = FLC(', 12, ') + XMAS(', 12, ')*(FLB(', 12, ') - C1068700
    . CAU('.[2.") x FLA('.[2.") ='. J012.5)
246 FORMAT (30X, ' CA('.12.') = CA('.12.') + THA('.12.')*FLA('.12.')*)C1C6890C
247 FORMAT (30X.' XI('.12.') = XI('.12.') + THA('.12.')*FLE('.12.')*)C1C69000
246 FORMAT ( * FLAC( '. 12. ') = XPC( '. 12. ') #FLA( '. 12. ') = '. 31x. 3012.5) C1C69100
249 FORMAT (" FLOC(".12.") = xMC(".12.")#FLU(".12.") =".31x.3012.5) (1069200
412 FORMAT (30x. ' CA('.12.') = '.3012.5)
                                                                                        C1 C69300
254 FORMAT (41x. 3012.5)
                                                                                        00440013
255 FURMAT (20x.' XI('.12.') = '.3012.5)
                                                                                        C1 C69500
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25t FCRMAT (/,' SVA = '.ZB.' ELEMENTS CF SET ARE '.1015./) C1C69600
257 FCRMAT (////.40x.'FLEXIELE BUJY '.13.//) C1C69700
256 FORMAT (30x,' BODY '.13.' EFFECTS CF ELASTIC NODE '.13./) %1C69800
258 FORMAT (15x,' ELASTICALLY DEF JRMED CENTER OF MASS VECTOR AND INERCIC69900
*11A TENSOR FCR BUCY '.13./)
FE TURN
ENC 01C70200
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```
C
                                                                        C1100000
      SUBRCUTINE ECIVIY.NEG)
                                                                        C1100100
C
      LSED TO SET UP INITIAL VALUES FOR RUNGE
                                                                        C1100200
C
                                                                        C1100300
C
                                                                        C1100400
      IMPLICIT REAL+8(A-H.O-Z.I)
                                                                        C1100500
      LOGICAL FOI. FOZ. FG3. FG4. FJS. INERF. HBLO. LEQU. LINIT(1)
                                                                        C1100600
                     LEUNGE . LTENSI . LVDIV . LEQUIV . LTEAN .
     LOGICAL
                                                                       C1100700
                      LTFANY . LHATE . LXUY . LETA . LTOHOU .
                                                                       C110080C
                     LOFDOT . LOCT . LANGLE . LSETUP . LSIMO
                                                                        C1100900
C
                                                                        C1101000
C
                                                                        C1101100
     INTECEN
                                                                        C110120C
     . ALDER . CTI
                   . CT2 . CT2 . CT4 . CT5 . FCON . FCCN . C1101300
                                    , SFKJUM, SFK , SFR , SG , C1101400
     . SCNCL4. SCN
                    . SCRDUP. SCA
                                                            . SLK
     • 51 • 516
                    . SIXDUP . SIX
                                                     . SL
                                     . SKOUM . SK
                                                                        C1101500
           . SACOUP. SMC . SMV
                                                                    . CIICI600
     . SHA
                                     . SCK . SPIDUM. SPI
                    SSCN . SSIX . SVA . SVB . SVD . SVI
SVQ . SXM . SXT . TUHQ . SMAL . SEU
NFLXB . SFLX . SFXM . NMUDS . SFCC . SCC
     . SCL
           . SR
                    . SSCN . SSIX . SVA
                                                                    · C1101700
           · SVP
     . SVM
                                                                    . (1101800
            . SC6
     • 50
                                                                        C1101900
     · IINIT(1)
                    . IZINIT(I)
                                     . 50
                                                                        C1102000
C
                                                                        C1122100
                                                                        C1102200
     SEAL .S
                                                                        C1 102 300
                    . CNF (2.10) . ETIC (3.10) . ETMC (3.10) . C1102400 . FLE (2.3.20). FLM (3.3.20). C1102500
     . ANGC (23)
     . FLO (2.20) . FLE
     . THACO (33)
                    . THED (2.2.11). RINIT (1) . RZINIT(1)
                                                                        01102600
C
                                                                        C1102700
C
                                                                        C1102800
C
                                                                        01102900
C
                                                                        C1103000
     CCMMCN /LDEBUG/ LRUNGE . LTRNS! . LVDIV . LEGGIV . LTRAN .
                                                                        (1103100
                     LIFANY . LHATE . LXDY . LETA . LTOFQU . LGFDOT . LCCT . LANGLE . LSETUP . LSIMQ
                                                                        C1123200
                                                                        C1103300
C
                                                                        C1103400
C
                                                                        C1103500
     COMMEN /LUGIC/ FG1. FG2. FG3. FG4. FG5. INEAF. RBLU(10)
                                                                        C1103600
C
                                                                        (1103700
C
                                                                        C1103800
     CUPMEN / INTS/
                     ADDRK (200)
                                                                        C1103900
                                                     . CT4
     . (11
                     . CT2
                                     . C13
                                                                     . (1104000
     · C15
                     . FCON (22)
                                   . JCCN (10)
                                                  . LCUN (22)
                                                                     . (1104100
                                    . Nd00
                                                     . NCTC
     . ..
             (10)
                    . NEI
                                                                       01104200
     . NEES
                     . AFKC
                                     . NFRC
                                                     . NLOR
                                                                        C1104300
                    . MPD
     . NEV
                                                     . ASVP
                                     . NHOA
                                                                       C1104400
                    . FCCN (111)
     . NEVC
                                    . 50
                                                     . SFR (33)
                                                                     . (1104500
                    . 11
     . 56
                                  . 316
                            ( 55)
                                                     · SL
                                                                     . 01104600
           (23)
                            (10)
     . SLK
                    . SMA
                                   . SUK (11)
                                                    · SQF
                                                            (11)
                                                                    . (1104700
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· SCL
             (11)
                    . SMV
                    . SMV
                                   . SR
                                                   . SSCN
                                                                  . (1104800
                                                                  . 01104900
                                    . SVd
                                                   . SVO
     . SSI x
                    . SVM
                                    . SVP
     . SVI
                                           (22)
                                                   . SVC
                                                          (33)
                                                                  . (1105000
             (3.10) . EXT
                                    . TURG (97)
                                                  . SMAL
                                                                   . (1105100
     * SXM
                                    . SC
                                                   . SCG
     . SEU
                    . NTO
                                            (13)
                                                                     (1105200
                                                                  . 01105300
     · NFL #3
                    . SFLX
                                    . SFXM (10)
                                                   . NHUDS
                                                                     C1105400
     . SFCC
                    . SCC (10)
                                                                     C1105500
C
C
                                                                      C1105e00
      COMMEN /INTGZ/
                                                                     C11C5700
                    . SCN
                                                  . SCH (9)
                          (5)
                                   . SCRDUM
                                                                  . (1105800
     . SCNCLA
     . SFKCLM
                                  . SIXDUM
                                                  . SIX (9)
                                                                   . 01105900
                    . SFK (5)
     . SKOLM
                                   · SPIDUM
                                                  · SPI
                                                           (9)
                    . SK
                            (5)
                                                                     C1106000
     . SECCLM
                    . SMC
                            (5)
                                                                      C1106100
C
                                                                     C1126200
c
                                                                     C1136300
     COMMEN /REAL/
                                                                     C1106400
     (10) , CCFC (3.11) , C110e500
(33) , FUMC (3.11) , C110e600
                                           (3.10) . HMC (3.10) . C11C67CC
                                                   . QF
                                                                     01106800
                                                          (3.32) .
                                          (12)
                                           (3.22) . KCMC (3.11) .
                                                                     C11C6900
                                                   . THAD (33)
                                     THA

    T

                                           (33)
                                                                     C1107000
                                   . XOIC (3.3.00). XI
                                                          (3.3.10). 01107100
                            (10) . XMN
(3.20) . FLU
                                                                    C1107200
     4 XIC (2.3.10). MAS (10)
                                          (33.33) . XMT
                                                          (3.2.16).
                                          (3.23) . FLC
     . TLG
            (35) . FLA
                                                          (3.20) .
                                                                     C1107300
     * FLD
            (3.3.20). FLJ
                           (2.3.20). CAU
                                                          (3.3.16).
                                                                     C1107400
     * FLIRC (2.10) . FLCRC (2.10) . FLAC (3.20) . FLUC (3.20) .
                                                                     (1107500
     • FLC+ (20) . ZETA (20) . FCF (3.3.40). FCA
                                                          (3.40) .
                                                                     C110760C
     CASMIT .
                                                                     C1107700
C
                                                                     01107800
C
                                                                     01107400
     CCMMCH /FEAL 2/
                                                                     C1100000
     * CEDLM (1.3) . CB (2.10) . CBCDUM(1.3) . CBC (3.10) . 
* XFCCL4(1.1.4) . XFC (2.3.10). CBN(3)
     • CEDLM (1.3) . C8
                                                                     CIIOMIOC
                                                                     C1108200
C
                                                                     C1108300
                                                                     C1108400
                                          . (XMN(1.1). ANGD(1))
     EULIVALENCE (ETM(1). THACC(1))
                                                                     C1108500
                 (XMN(1.3).YMCD(1.1.1))
                                          . ( XMN ( 1 . 0 ) . CNF ( 1 . 1 ) )
                                          .(AMN(1.0).CNF(1.1)) .
                                                                     01108600
                 (XMN(1.8).ETIC(1.1))
                                                                     C11C8700
                                          . (FLE (1.1.1).FLD(1.1.1)).
                 (FLd(1.1).FLQ(1.1))
                                                                     C1108800
     .
                 (FLM(1.1.1).FLJ(1.1.1))
                                                                     C11C8900
                                          .(CA(1.1). MINIT(1))
                                                                     01109000
                 (FGI.LINIT(11)
                                          . (A.OFK(1). [[N[T(1)]
                                                                     01109100
                 (CHDUM(1.11.FZINIT(11))
                 (SCNOUM. IZINIT(1))
                                                                     0.026.0113
                                                                     C1169300
C
      INTEGER STILLI
                                                                     20000113
     FOUTVALENCE (LEGUTY.LEGUT
                                                                     C110950#
                                                                     C1104000
C
     CINENSIEN VINEGI
                                                                     (1109700
C
                                                                     C1109800
                                                                     C1109900
C
     ANGULAR CH LINEAR RATE WITH RESPECT TO FREE ARES
                                                                     C1110000
     IF (LEJUJFHINT 100
                                                                     C111010C
      IF (LEUU IPRINT 101 . NFER
                                                                     00201113
     CO I N=1.NFEH
                                                                     C1112300
                                                                     C1110400
      Y(h) = THAU(N)
                                                                     (1110500
      IF (LEGUJFRINT 102 . N.N.YIN)
    I CUNTINUE
                                                                     C11110600
     AN & AFER
                                                                     C1110700
```

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C
                                                                            (1110800
                                                                            C11110900
C
      GENERALIZED ELASTIC COCRCINATE HATE EJUATIONS
                                                                            C1111000
      IFILEGUI PRINT 112. NMODS
                                                                            C1111100
      IF (NMO) 5 . EQ. C) GU TO 7
                                                                            C1111200
      CO 7 N=1.NMUDS
                                                                            C1111300
      NA = NN + N
                                                                            C1111400
      Y(NA) = THAD(NA)
                                                                            C1 11 1500
      IF (LEGU) PRINT 102. NA. NA. Y(HA)
                                                                            C11111600
    7 CENTINUE
                                                                            C1111700
      AN = AA + NHODS
                                                                            C1111800
                                                                            C1111900
                                                                            C1112000
C
      HELATIVE ANGULAR MEMENTUM OF WHEEL
                                                                            (1112100
      (ALL UNPAC(STI.NSTI.SMV)
                                                                            C1112200
      IF (LEGUJFRINT 103. NST1
                                                                            C1112300
      IF(NST1.60.0) GO TC 5028
                                                                            C1112400
      CO 2 NAM=1.NST1
                                                                            C1112500
      N= NS 11 - (NNN- 1)
                                                                            C1112600
      MA = NN + NST1 + 1 - N
                                                                            C1112700
      T(NA) = THADA(STI(N))
                                                                            CI 112800
      IFILEQUIFRINT 104. NA.STIINI.Y(NA)
                                                                            CI 112900
    2 CONTINUE
                                                                            C1113000
 SOZE CONTINUE
                                                                            C1113100
      NN = NN + NMV
                                                                            C1113200
                                                                            C1113300
      CISPLACEMENT ABOUT UR ALONG FREE AXES
                                                                            C1113400
      IF (LEGU) FRINT 105. NENC
                                                                            CI113500
      IF (NFRC . EQ . 0) GO TC 5029
                                                                            C1113600
      CO 3 N=1.NFRC
                                                                            CI 11 3700
      . . SFH(N)
                                                                            C1113800
      MA = NN+N
                                                                            C1113900
      TENANT = THALM)
                                                                            C1114000
      IF (LEGU) FRINT 106 . NA. P. Y(NA)
                                                                            C1114100
    2 CONTINUE
                                                                            C1114200
 5025 CCATINUE
                                                                            C111430C
      AN = AN+AFRC
                                                                            C11114400
C
                                                                            C1114500
                                                                            C1114600
      CENERALIZED ELASTIC COORCINATE DISPLACEMENT EQUATIONS
                                                                            C1114700
      IFILEGUI PHINT 112. NMCDS
                                                                            C1114800
      IF (N+COS.EQ. C) GO TO 9
                                                                            C1114900
      CG 9 A= 1 . NMUDS
                                                                            C1115000
      NA = NN + N
                                                                            C1115100
      ASTI = AFER + N
                                                                            01115200
      TINAL = THAINSTIL
                                                                            C1115300
      IF (LEGU) PRINT 136. NA.NSTI.Y(NA)
                                                                            C1115400
    S CONTINUE
                                                                            C1115500
      AN = AN . NMLES
                                                                            C1115600
C
                                                                            C1115700
C
                                                                            C111580C
      CISPLACEMENT ABOUT MHEEL SPIN ANIS
C
                                                                            C1115900
      IFILEQUIFHINT 107. NHOA
                                                                            01116000
      IF (N+CA.EG.O) GO TC 5030
                                                                            C1116100
      CU 4 N=1.NMOA
                                                                            C1116200
      . . SMACAL
                                                                            C111630C
                                                                            C1116400
      Y(NA) = THAM(M)
                                                                            C1116500
      IFILEQUIFRINT ICH. NA.P.Y(NA)
                                                                            01116600
    4 CCATINUE
                                                                            C1116700
```

```
EDJC CONTINUE
                                                                            (1116800
      NN = NN+ NMUA
                                                                            C1116900
                                                                            C1117000
                                                                            (1117100
      CIRECTICA COSINES
C
      (ALL UNPACISTI .NSTI .SD)
                                                                            C1117200
      IF (LEQU) FRINT 109. SD. (STI(1). I=1.NST1)
                                                                            C1117300
      IFILEGUIFHINT IIC. INERF
                                                                            C1117400
      IF (NST1 . EQ. 0) GO TC 5031
                                                                            C1117500
      A = AN
                                                                            C1117600
      h = (
                                                                            C1117700
      IF (INERF . OR . STI(NSTI) . NE . I) GU TO 5
                                                                            C1117800
      ASTI = ASTI - 1
                                                                            C1117900
      CO 8 J=1.2
                                                                            C1118000
      CO 8 I=1.3
                                                                            C1118100
      NN = NN +1
                                                                            C1118200
      Y(NN) = MC(1.J.M)
                                                                            C1118300
      IF (LEGU) FRINT III. NN. I ... M.Y(NN)
                                                                            C1118400
    & CONTINUE
                                                                            C1118500
    5 IF (NST1 . EQ . Q) GO TC 5031
                                                                            C1118600
      CO 6 N=1.NST1
                                                                            C1118700
      . = STI(N)
                                                                            C11118800
      CO 6 J=1.2
                                                                            C1118500
      CO 6 1=1.3
                                                                            C1119000
      NN = NN + 1
                                                                            C1119100
      Y(NN) = XMC(I.J.M)
                                                                            C1119200
      IF (LEGUIPHINT III . NN. I ... . . Y(NN)
                                                                            C1119300
    & CONTINUE
                                                                            C1119400
 5021 CONTINUE
                                                                            C111950C
      NEG = NA
                                                                            CI 11 9600
                                                                            C1119700
  100 FORMAT ("1 ENTER SUBMOUTINE EGIV ")
                                                                            C1119800
  101 FORMAT ( * NFER = 1.15)
                                                                            CI 11 9900
  102 FORMAT (' Y('.12.') = THAC('.12.') = '.015.5)
                                                                           (1120000
  103 FORMAT ( .
                 NST1 = 1.151
                                                                            (1120100
  104 FCRMAT (' Y('.12.') = THADB('.12.') = '.015.5)
                                                                            C112220C
  105 FORMAT ( * NFRC . .. 15)
                                                                            C1120320
  106 FORMAT ( * Y('.12.') = THA('.12.') = '.015.5)
                                                                           C1120400
  107 FORMAT ( .
                 NELA = 1.15)
                                                                            (1120500
  108 FORMAT (' Y('.12.') = THAB('.12.') = '.D15.5)
                                                                            C1120600
  109 FORMAT ( ' SD = '.ZE. ' ELEMENTS IN ARRAY STI ARE '.1015)
                                                                           C1 120700
  110 FORMAT ( ! INERF : .. LIO)
                                                                           C112080C
  111 FORMAT (' Y('.12.') = X+C('.12.','.12.','.12.') 4 '.015.5)
                                                                            C112090C
  112 FORMAT (* NEODS **.15)
                                                                            C1121000
                                                                            C1121100
      RETURN
                                                                            0.0212113
     ENC
                                                                            C1 12 : 300
                                                                           C1400000
C
     SLERCLTINE THAN
                                                                           C12001C0
     COMPLTE ALL TRANSFERMATICA MATHICES
C
                                                                           C1200200
       I ) USE ORTHOGONALITY TO GET MISSING ELEMENTS
                                                                            C1220300
C
¢
        2) CONSTRUCT OTHERS NOT IN SO
                                                                           C1200400
                                                                           C1200500
C
     IMPLICIT REAL . B(A-H.O-Z.1)
                                                                           C1200600
C
                                                                            C1200700
C
                                                                           (1200800
```

```
LOGICAL FUL. FG2. FG3. FG4. FG5. INERF. RULU. LEQU. LINIT(1)
                                                                      01200900
                     LTEANY . LEATE . LXDY . LETA . LTGEOU .
      LOGICAL
                                                                         01201000
                     LIFANY , LEATE , LXDY , LETA , LTGEQU , LGFDOT , LDCT , LANGLE , LSETUP , LSIMQ
                                                                         01201100
                                                                         C1201200
                                                                         C1201300
C
C
                                                                          C1201400
      INTECER
                                                                          C1201500
                                    . CT4 . CT5 . FCCN . PCON . C1201600
     . ANGRE . CTI
                     . CT2 . CT3
     . SCNEUP. SCN
                   . SCROUP, SCR
                                    . SFKDUM. SFK . SFR . SG
                                                                         C1201700
                                                              . SLK
                                                     . SL
     . 51
           . SIG
                     . SIXDUM. SIX
                                     . SKDUM . SK
                                                                         C1201800
     . SHA
             . SHCDUM. SHC . SMV
                                            . SPIDUP. SPI
                                                              . SQF
                                                                          C1271900
                                     . SUK
                             . SE1x . SVA
                                                              . SV 1
                    . SECN
                                                                         C1202000
     • S.C.
                                             . SVD . SVD
             . SR
            . SVP
     . 5.4
                     . SVQ . SXP
                                     . SAT
                                             . TOHU . SMAL . SEU
                                                                         C1202100
                   . MFLXB . SFLX . SFXM . NMUDS . SFCC . SCC
                                                                     . 01202200
     • SC
            · SCG
     · IINIT(I)
                     . IZINIT(1)
                                     . 50
                                                                          C1202300
C
                                                                          01202400
C
                                                                         C1202500
      FEAL ..
                                                                          01202600
            (33) . CAF (3.10) . ETIC (3.10) . ETMC (3.10) (2.20) . FLE (2.3.20). FLM (3.3.20). (23) . YMCD (2.2.11). RINIT (1) . MZINIT(1)
     . ANGC (33)
                                                                         C1202700
     . FLO
                                                                          C1202600
     • THACO (33)
                                                                         01202900
C
                                                                         C1203000
C
                                                                         C1203100
C
                                                                         C1203200
                                                                         C1203300
C
      CCMMCN /LDEBUG/ LRUNGE . LTHAS! . LVDIV . LEGUIV . LTHAN .
                                                                         C120340C
                      LIFANY . LEATE . LXDY . LETA . LTDEQU .
                                                                         01203500
                      LOFDOT . LOCT . LANGLE . LSETUP . LSING
                                                                         C1203600
C
                                                                         C12037C0
                                                                         01203800
C
     COMMON /LUGIC/ FG1. FG2. FG3. FG4. FG5. INERF. MBLJ(10)
                                                                         C1233900
C
                                                                         C1204000
                                                                         C12C4100
     COMMEN /INTO/ ADURK(200) .
                                                                         C122420C
                    · C12
                                                     . CT4
     • CT1
                                     · CTJ
                                                                         C1204 300
     · C15
                     . FCON (23)
                                    . JCON (10)
                                                      . LCON (22)
                                                                      . 01294400
     . MC
             (10)
                    . NO1
                                     · NUCU
                                                     . NCTC
                                                                         C1 . 04500
                                     . NFRL
                                                     . NLOH
     . NEEE
                     . NEKC
                                                                         01204600
                     . ANG
     . NHV
                                     . NACA
                                                     . NSVP
                                                                         C12047C0
     . NEVC
                     . FCON (111)
                                     . 50
                                                     . SFR (33)
                                                                         01204800
                                   . 516
     . 56
                    . 51
                             (::)
                                                     . SL
                                                                         C1204900
                     . SMA
                                           (11)
                                                     . SQF
     . SLK
             1 3 4 4
                             (10)
                                     . 5GA
                                                             (11)
                                                                         C120500C
                     . SHY
                                     . 54
                                                     . SSEN
     . SCL
            (11)
                                                                         01225100
                     . TVA
     . 551×
                                     . ...
                                                      . SVC
                                                                         0.0520510
     . Sv1
                     . SVM
                                     . SVP
                                             (22)
                                                     . 540
                                                             (33)
                                                                         C122530C
                                                                      .
                                     . TUFU (17)
     . ...
            (3.13)
                    . SAT
                                                     . SMAL
                                                                         00440513
                                                     . 506
     · SEU
                     . ATO
                                     . 36
                                             (33)
                                                                        (1205500
     * NFL PO
                     . SFL K
                                     . SF XM (10)
                                                      . AMOUS
                                                                      . 01205600
     · SFCC
                            1101
                                                                         C1205700
                     . 56.5
C
                                                                         C1205800
C
                                                                         01205900
      COMMEN /INTOZ/
                                                                         2000000
     . SCNELM
                                    . SCHOUM
                     . SCN
                             151
                                                     . SCH
                                                             641
                                                                         02140513
                                     . SIXDUM
     . SPECLM
                     . SFR
                             151
                                                     . 51x
                                                             (4)
                                                                         01206200
                                                     · SPI
     . SKOLM
                                     · SPIDUM
                                                                        C1206300
                     . SK
                             151
                                                             (4)
     · SPCCLM
                    . SMC
                             151
                                                                         01406400
                                                                         01226500
C
                                                                         01226600
C
     CCHMIR THEALT
                                                                         C12067C0
     • CA (3.10) , CAC (3.10) , CLM (10) , CLMC (3.11) , C1206800
```

```
. DCMC (3.11) . ETC (3.11) . ETM
                                                  (33)
                                                            . FCMC (3.11) . C12C6900
              (2,00) , P
(10) , PHI (2,11) , PLP
(3,33) , GL (2,22) , QLC
                                                   (3.10) . HMC (3.17) . C1207000
      . GAM
                                                            . QF
      4344 .
                                                  (10)
                                                                     (3.33) . 01207100
      · QFC
                                                  (3.22) . HOME (3.11) . C1207200
                                                                                  C1207300
                                            TriA
                                                  (33)
                                                           . THAD (33)
                                          . XCIC (3.3.66). XI
      . THAC. (10)
                       . THA. (10)
                                                                     (3.3.10).
                                                                                  C1207400
              (2.3.10). XMAS (10)
                                                                    (3.3.10). 61207500
                                         . XMN
                                                   (33,35) . XMT
      * XIC
                      . FLA (3.20) . FLO
      * TLG (23) , FLA (2:20) , FLD (3:20) , TLG (3:3:10) .

* FLD (3:3:20), FLJ (3:3:20), CAO (3:10) , XIC (3:3:10) .

* FLIFC (3:10) , FLCPC (2:10) , FLAC (3:20) , FLUC (3:20) .

* COOL (50) - ZETA (22) , FCF (3:3:40), FCK (3:40) .
      . TLG
              (23)
                                                 (3.20) . FLC (3.20) . C1207600
                                                                                 01207700
                                                                                  C1207800
                                                                                 C12C7900
                                                                                  C1208000
      . TIMENO
                                                                                  01208100
C
C
                                                                                  C1208200
      COMMEN /FEALZ/
                                                                                  C1208300
      . CEDLA (1.3) . CE
                               (3.10) . CJCDJM(1.3) . CBC (3.10) . C1208400
      • XMCCL4(1.1.9) . XMC (2.3.13). Cah(3)
                                                                                  C1208500
C
                                                                                  C1208600
C
                                                                                  C1204700
      EQUIVALENCE (ETM(1). THACE(1))
                                                 . ( AMN ( 1 . 1 ) . ANGD ( 1 ) )
                                                                                  C1208830
                    (XMN(1.3).YMCD(1.1.1))
                                                 . ( KMN (1.6) . CNF (1.1))
                                                                                  (1208900
                    (XMN(1.6).ETIC(1.1))
                                                 . ( XMN (1 . 10) . E TMC (1 . 1) )
                                                                                  01209000
                                                                                  01209100
                    (FL3(1.1).FLG(1.1))
                                                  · (FLE (1.1.1).FLD(1.1.1)).
                    (FLM(1.1.1).FLJ(1.1.1))
                                                                                  C1209200
      ٠
                                                                                  01209300
                    (Fil.LINIT(11)
                                                 . ( CA( 1 . 1 ) . H [N( 1 ( 1 ) )
                    (CBDUP(1.1).FZINIT(1))
                                                 . (ADDRECT) : SINIT(1))
                                                                                  £1209400
                    (SCHOLP. IZINIT(1))
                                                                                  C1209500
6
                                                                                  C1209600
      LOCICAL CTAIN
                                                                                  01209700
       CINEPSILA TEMPICA.31
                                                                                  C1209800
      CIMENSILA AMS(3.3).0(2).65(2).TEM(3.2).TEMP(3.3)
                                                                                  01209900
      INTECEN STILLOI.SETLIDI
                                                                                  C1210000
      EQUIVALENCE (LTRANILEGE)
                                                                                  (1:10100
C
                                                                                  01210200
C
                                                                                  01210300
                                                                                  C1410400
       IF (.ACT. LEGU) GC TO 1000
                                                                                  C1210500
      FRINT 100
                                                                                  (1210600
       20 = C
                                                                                  (1210700
       -1 = 1
                                                                                  C1210800
       12 = E
                                                                                  C1213500
       43 = 3
                                                                                  C1211200
       FRINT ICL. INCAF
                                                                                  C1211100
 173C CALL UNPAC (SET.NECT.SO)
                                                                                  (1211200
       IF (LEGUIFAINT 102 . SD . (SET(1) . I=1 . NSLT)
                                                                                  C1211300
       IF (NSET.EU.0) 60 10 5922
                                                                                  C1211400
      KST . I
                                                                                  01211500
       IF ( INERF .UH . SET( NSET) . NE . I ) GJ TJ I
                                                                                  C1211600
      ASET = ASET - 1
                                                                                  C1211700
      AST . 0
                                                                                  CLALINGO
                                                                                  C1211900
       # E E
     I BKEKST
                                                                                  C1212000
       IF (K!T.GT.NSET IGO TO SCEE
                                                                                  C1212100
5021 IF (KR. LG. 0) GU TO 19
                                                                                  C1212200
       R S SET(KK)
                                                                                 C1212300
   IS CALL VECTOS (AMC(I.I.K). AMC(I.Z.A). AMC(I.J.A))
                                                                                 C1212400
       IF (. + cf . LEUU) GO TO 2
                                                                                  C1212500
      FRIAT 154
                                                                                  C1212600
      FRINT 115.
                    ( AMC (1 . 1 . K ) . [ = 1 . J )
                                                                                  01212700
      FRINT 116.K. ( XMC(2.1.K).(=1.1)
                                                                                  C1212800
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FRINT 115. (AMC(3.1.K).1=1.3)
                                                                             C1212900
                                                                             C1213000
    2 CCATINUE
      KK=KF+1
                                                                             C1213100
      IF (KK.LE.NSET) GO TO 5021
                                                                             C1213200
SO22 CENTINUE
                                                                             C1213300
                                                                             C1213400
          COMPLTE ELEMENTS OF THANSFURMATION MATRICES OBTAINABLE
                                                                             C1213500
C
C
          VIA SMALL ANGLE ASSUMPTIONS OR EULER ANGLES
                                                                             C1213600
                                                                             C1213700
C
      15 = Sn - SD
                                                                             C1213800
      CALL UNFAC (SET . NSET . 15)
                                                                             C1213900
      (ALL UNPACISTIONSTIOSMAL)
                                                                             C1214000
      IF ( . NoT . LEGU) GO TO 3
                                                                             C1214100
      FRINT 107. IS. (SET(1).1=1.NSET)
                                                                             C1214200
      FRINT 10.
                                                                             C1214300
    3 IF (NEET.60.0) GO TC 5032
                                                                             01214400
      CO 4 III = 1 . NSET
                                                                             C1214500
      JJJ=NSLT-(111-1)
                                                                             20941312
      .J = SET(JJJ)
                                                                             C12147C0
       a JCCN(JJ)
                                                                             C121480C
      CO 20 1=1.3
                                                                             C1214900
      CO 2C L=1.3
                                                                             C1215000
   20 1EMP(1.L) = XMT(1.L.JJ)
                                                                             061215130
      CHECK FOR THREE CONSTRAINED AKES
                                                                             C1215200
      IF (PCCN (JJ).NE.J) GC TC 5026
                                                                            C1215300
      CC 27 1=1.3
                                                                             C1215400
      CO 27 L=1.3
                                                                            C1215500
      AME(I.L) = TEMP(I.L)
                                                                            C1215600
   27 CONTINUE
                                                                             C1215700
 SOZE CONTINUE
                                                                             C1215800
      MOCNE . 3-PCCN(JJ)
                                                                             01215900
      CO 5 11:1. MD CNE
                                                                            20091312
      1 : 11-1
                                                                            01210100
      CYCLE THROUGH FREE COORDINATE HOTATIONS AT HINGE FOINT JJ-1
                                                                            C1216200
C
      · = 53F(33) + 1
                                                                             00661513
      (LL.1+1) WX : 8*
                                                                            C12164C0
      CHECK SMALL ANGLE ASSUMPTIONS
                                                                            C1216500
      E . THALES
                                                                             C1216600
      C = 1.300
                                                                             C1216700
      IFICTAIN(JJ.STI.NSTI)) GC TC 22
                                                                            C12168CO
      B . CSIN(THA(M))
                                                                            00001513
      C = CCOS(THA(M))
                                                                            C1217000
   22 CONTINUE
                                                                            C1217100
      IFI.ACT.LEGUI GU TC 5027
                                                                            C1217200
      PRINT 120. JJ. J. I.M.Ke.E.C.
                                                                            C1217300
 120 FORMAT (" JJ =".13." J =".13." 1 =".13." M =".13." NB =".13." B ="01217400
     .017.d. ( a .. 017.e)
                                                                            01217500
 5027 CONTINUE
                                                                             C1217600
                                                                            C1217700
      CALL HUTTE.C.KE.TEMPIT
      CALL MATPULITEMP. TEMP1 . x . 5.21
                                                                            C1217800
                                                                            C1217900
      DO 25 6=1.3
      CO 2: LL=1.3
                                                                            C1218000
      TEMP (L.LL) = XMS(L.LL)
                                                                            COLBIGIO
  25 CCATINUE
                                                                            C1218200
    S CONTINUE
                                                                            C1216300
      IF (LEGU) PHINT 118. ((TENF(1.L).L=1.3).1=1.3)
                                                                            C1218400
      (ALL MATPUL(XMT(1.1.JJ). 1EMF.XMS.J)
                                                                            C1218500
      IFI.ACT. LEGUI GO TO 1002
                                                                            C1214600
      PRINT 104
                                                                            C1218700
                                                                            C1218800
      FHINT 125. (AMS(1.1).1:1.2)
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FRINT 11C. JJ. (xMS(2.1).1=1.3)
                                                                              C1218900
      PRINT 105. (XMS(3.1).1=1.3)
                                                                              C1219000
      FRINT 134
                                                                              C1219100
 1002 IF (J.NE.C) GO TO 16
                                                                              C121920C
      IF (INEMF) GU TC 17
                                                                              C1219300
      CO 15 1=1.3
      CO 15 L=1.3
                                                                              01219500
   IE AMC(I.L.C) = XMS(L.I)
                                                                              C1219600
      IF (.NOT. LEGU) GO TO 4
                                                                              C1219700
      FRINT 112. (XMC(1.1.0).1=1.3)
                                                                              (1219800
      FRINT 112. J.JJ. ( **C(2.1.0) .1=1.3)
                                                                              C1219900
      FRINT 112. (XMC(3.1.0).1=1.3)
                                                                              C1223000
      FRINT 1CA
                                                                              01220100
      CC TC 4
                                                                              (1220200
   17 CO 16 1=1.3
                                                                              C122030C
      CO 16 L=1.3
                                                                              C1220430
   IE MC(I.L.I)=XMS(I.L)
                                                                              C1220500
      IF (. NOT . LEGU) GU TO 4
                                                                              C1220e00
      FRINT 112.(AMC(1.1.1).1=1.3)
                                                                              C1220700
      FRINT 114. JJ.JJ. (*MC(2.1.1).[=1.3)
                                                                              C1220800
      FRINT 112. (AMC(3.1.1).1=1.2)
                                                                              C1220900
      CO TC .
                                                                              C1221000
   16 (ALL MATMUL( #40(1 .1 . J) . #45 . #40(1 .1 . JJ) . 3)
                                                                             C1221100
      IF ( . ACT . LEGU) GO TO 4
                                                                              C1221200
      FRINT 105. (XMC(1.1.JJ).(=1.2)
                                                                              C1221100
                                                                              C122140C
      FRINT 1CC. JJ.J.J.. (XMC(2.1.JJ).1=1.3)
      FRINT 105. (XMC(3.1.JJ).1:1.2)
                                                                             C1221500
      FRINT 104
                                                                              C1221600
    4 CCATINUE
                                                                              (1221700
 5032 CUNTINUE
                                                                              00815510
C
                                                                              01221900
      LPCATE THANSFORMATION MATRICES ASSOCIATED WITH LINEAR OSCILLATORS C1222000
      CALL UNPACISET . NSET . SLI
      IF (NEET . EQ. 0) 40 TC 5033
                                                                              011222200
      CO 12 JJJ=1 -NSET
                                                                              01222300
      .J = SET(JJJ)
                                                                              C1222400
      J . JCCMIJJI
                                                                              01222500
      CO 14 1:1.3
CO 14 L:1.3
                                                                              C1422600
                                                                              C1222700
   14 XMC(1.L.JJ) = XMC(1.L.J)
                                                                              C1 222 HOC
      IF (LEGUI PRINT III. JJ.J
                                                                              C1222900
   13 CCATIANE
                                                                             C1 22 3000
 6032 CONTINUE
                                                                              C1223100
      IF (LEGU) PRINT 104
                                                                             C1221200
  170 FORMAT ("1 SUBROLTINE TRAN ENTERED ".//)
                                                                             C1 22 1300
  101 FORMAT (" INERF . ".L5./)
                                                                             C12234C0
  102 FORMAT (*
                 SD = ".ZE." SET ELCHENTS AND ".1015.//)
                                                                             00265313
  104 FORMAT ( . .)
                                                                             C1223600
  105 FORMAT (30x.3017.e)
                                                                             C1223700
  ICE FORMAT (' AMC('.12.') . AMC('.12.') *AMS('.12.') . '.3017.8)
                                                                             C1223400
  127 FORMAT (*
                    SR-SC = './8. ' SCT ELEMENTS ARE '.1015.//)
                                                                             £1 22 1900
  109 FORMAT ( 12x . 3017 . e)
                                                                              C1224000
  110 FURMAT ( * XMS( *. 12. *) * *.3017.8)
                                                                              C1:24100
  111 FORMAT (/. * XMC( *.12.*) . AMC( *.12.*) *)
                                                                              C1224200
  112 FORMAT (454.3017.6)
                                                                             C1 224 300
  113 FORMAT (* AMC(*.12.*) . AMS(*.12.*)*** . ..3017.6)
                                                                             C1224400
  114 FCEMAT (' XMC('.12.') = XMS('.12.') = '.3017.0)
                                                                             C1224500
  115 FORMAT (124.3017.8)
                                                                             C1 224600
 116 FORMAT (* XMC(*.12.*) = *.2017.6)
116 FORMAT (* TEMP = *.3017.6)
                                                                             C122470C
                                                                             C1224800
```

```
C
                                                                            C1220000
     SUBRCUTING TRANVO
                                                                            C1300100
C
      TRANSFURES UNLY THESE VECTORS AND DYADS TIME VARYING IN
                                                                            C1300200
      CCMELTING FRAME
                                                                            C1 320 300
C
                                                                            C1200400
C
                                                                           C1 300500
c
     IMPLICIT HEAL+8(A-H.O-Z.1)
                                                                            C1200600
     LOCICAL FGI. FG2. FG3. FG4. F .S. INERF. RBLD. LEGU. LINIT(1)
                                                                            C1300700
     LCCICAL
                      LELNGE . LTRASI . LVDIV . LEGGIV . LTRAN .
                                                                           C1 300 800
                      LTRANV . LRATE . LXDY . LETA . LTOROU .
                                                                           C1 3CC900
                      LOFDOT . LOCT . LANGLE . LIETUP . LING
                                                                           C1301000
C
                                                                            C130110C
•
                                                                           C1301200
     INTEGER
                                                                            C1301300
    • ABCEK , CTI , CT2 , CT3 , CT4 , CT5 , FCUN , PCCN , C1301400
• SCNCUM, SCN , SCRDUP, SCR , SFRDUM, SFK , SFH , SG , C1201500
• SI , SIU , SIXDUP, SIX , SKDUN , SK , SL , SLK , C1201600
     . SHA
             . SMCDUP. SPC . SMV
                                      . SOK . SPIDUM. SPI
                                                               . SQF .
                                                                           C1301700
                    . SSCN
                                                               . SV I
                              . SSIX
                                                                          C1301800
           . Sh
     · SCL
                                      . SVA
                                               . SVB . SVD
            SVP SVO SEF SET TONG SMAL SEU .
SCG NFLEB SFLE SFEM NMGDS SFCC SCC .

(1) IZINIT(1) SD
            . SVP
                                                                            C1 301 900
     . SVM
                                                                           C1302000
     • 50
     . IINIT(1)
                                                                            C1302100
                                                                            C1202200
C
                                                                            C1302300
C
     LEAL . C
                                                                            C1332400
                    . CAF (3.10) . ETIC (3.10) . ETML (3.10) . C1302500
    . ANGE (23)
    • FLQ (3.20) . FLE (3.3.20). FLH (3.3.20).
                                                                            C130260C
                   . YMCD (2.2.11). MINIT (1) . MZINIT(1)
     . THACD (23)
                                                                            C1202700
C
                                                                            C1302800
C
                                                                            01 302900
C
                                                                           C1303000
C
                                                                           C1303100
     CCHMEN /LOEDUG/ LRINGE . LIANSI . LVDIV . LEGULV . LTRAN . LTANV . LRATE . LXDY . LETA . LTONGU .
                                                                           C1303200
                                                                           C1 30 1300
                      LOFDOT . LOCT . LANGLE . LILTUP . LING
                                                                           C1303400
C
                                                                           C1303500
                                                                            (1303600
     COPMEN /LOUIC/ FG1. FG2. FG3. FG4. FGg. INCAF. HOLD(10)
                                                                            C1303700
C
                                                                            C1303800
                                                                            C13C3900
     COMMEN /INTG/ ANCAMIZOOD.
                                                                            C1 204000
                                      . 613
                                                      . 614
     • (11
                     . 612
                                                                           C1304100
                                      . JCON (10)
     . (15
                     . FCGN (33)
                                                       . LCCN
                                                              (22)
                                                                           C1294200
     . ..
                    . NO.
                                      · NUID
                                                       . NCTC
            6 40 3
                                                                           C1304300
     . NFE .
                     . AFRC
                                      . NEWC
                                                       . NLOR
                                                                           C1204400
                     . ...
                                                       . ASVP
     . ...
                                      . NHUA
                                                                            C1 304500
                                                       . SFR
     . NEVE
                     . FCCN (111)
                                     . 50
                                                               (23)
                                                                           C1 304 600
                             ( 55)
                                    . 516
                                                      . SL
     . 90
                    . 51
                                                                           C1304700
                   . SMA
                                     . SUK (11)
                                                      . SQF
     · SLK
            4 3 3 3
                             (10)
                                                               (11)
                                                                           C1304800
     · SCL
             (11)
                     . 184
                                      . SR
                                                       . SSCN
                                                                            C1 204900
                                      . 546
                                                       . SVD
     . 551 .
                     . ...
                                                                            C1 305000
                                      . SVP (22)
     . 5 . 1
                     . ...
                                                                        . (1305100
                                                      . SVQ (33)
                                                       . SMAL
     . ...
            (2.10) . SET
                                     . TURG (47)
                                                                       . (1305200
```

```
. SC (33) . SCG
. SFXM (10) . AMCDS
      . SEU
                      . ATG
                                                                                · C1305300
      · NFL XO
                      . SFL X
                                                                                . 01305400
      . SFCC
                       . SCC (10)
                                                                                    C1 305500
C
                                                                                    C1 305600
C
                                                                                    £1.305720
      CCHMEN /INTGZ/
                                                                                    01305800
                                                                               . (1305900
                                                            . SCF (9)
      • SCNCLM . SCN (9) . SCROUM
                       . SFK (5)
                                                                               . (1306000
      . SFKCLM
                                          . SIXCUM
                                                            . SIX (9)
                       . SK
     * SPCCLM
                                                            · SPI
                                                                               . C1306100
                                 (5)
                                          . SPIDUM
                                                                      (9)
                               (9)
                      . SMC
                                                                                    C1306200
                                                                                    C1 20e 300
C
                                                                                    C1306400
      CONMEN / FEAL!
                                                                                    01306500
     • CA (3.10) . CAC (3.10) . CLM (13) . CCMC (2.11) .
• DCMC (3.11) . ETC (3.11) . ETM (33) . FUMC (3.11) .
                                                                                   00300610
                                                             . FUMC (3.11) . 01306700
            (2.66) . F . HM
(10) . PF1 (2.11) . PLM
(3.33) . GL (3.22) . ULC
THA
                                                  (3.10) . HMC (3.10) . C120680C
(10) . GF (3.32) . C130690C
(3.22) . FCMC (3.11) . C1307000
      . GAM
      . ....
      • QFC
                                                                                . 01307100
                                            THA
                                                   (33) . THAD (33)
      • T
     • THACO (10) . THAO (10) . NOIC (3.3.66). XI
• XIC (2.3.10). XMAS (10) . XMN (33.33) . XMT
                                                                      (3.3.10). 01307200
              (2.3.10). XMAS (10) . XMN
(23) . FLA (2.20) . FLB
                                                                      (3.3.10). 0130/300
     • TLG (33) , FLA (3.20) , FLB (3.20) , FLC (3.20) , C1307400
• FLD (3.3.20), FLJ (3.3.20), CAU (3.10) , A1U (3.3.10), C1307500
• FLIRC (3.10) , FLCRC (3.10) , FLAC (3.20) , FLQC (3.20) , C1307600
     • FLC + (20)
                      . ZETA (20) . FOF (3.3.40). FCK (3.40) . C1397700
      . TIMENO
                                                                                    C1 327800
                                                                                    C1 307900
C
C
                                                                                    C120H0C0
      CCOMEN /FEAL 2/
                                                                                    (1338100
     • CEDUM (1.3) • CF (3.10) • CBCDUM(1.3) • CBC (3.10) • C1208200
• XPCCU4(1.1.4) • XPC (3.3.13) • CBN(3) C1308300
C
                                                                                    01228400
C
                                                                                   C120850C
      EQUIVALENCE (ETM(1). THADE(1))
                                                  .(AMN(1.1). 44CD(11)
                                                                                   C120860C
                    (XMN(1.3).Y#CD(1.1.1))
                                                   . ( XMN(1.6). CNF (1.11)
                                                   .(AMN(1.6).CNF(1.1)) .
                                                                                   C1224700
                                                                                  (1338900
                    (AMN(1.0).ETIC(1.1))
                    (FLO(1.1).FLQ(1.1))
                                                   . (FLE (1.1.1). FLO(1.1.1)).
                                                                                  C1308900
     ٠
                    (FLH(1.1.1).FLJ(1.1.1))
                                                                                    C1309000
     ٠
                    (FGI.LINIT(11)
                                                   . (CA(1.1).@[NIT(1))
                                                                                    01309100
                                                  . (A-UNK(1). [[N[T(1))
                    (CEDUM(1.1).EZINIT(1))
                                                                                   01309200
                    (SCNDLM. IZINIT(I))
                                                                                   C1 229 100
C
                                                                                    C1304400
      LOGICAL CTAIN
                                                                                    C1309500
                                                                                    C1339600
      CINERSICA TEMESI
                                                                                    C1 304700
      CIMENSICA TEMI(3.3)
                                                                                    (1309800
      INTECEH STICIOI. SETCIOI. SF x+4
      EGUIVALENCE (LTRANV.LEGU)
                                                                                    C13C9900
                                                                                   C1210000
C
      IF (LEUU ) FRINT 200
                                                                                   C121010C
C
                                                                                    01310200
                                                                                    C1 31 3300
     ELASTIC CEFURMATICA PARAMETERS
                                                                                   C1310+00
C
                                                                                   01310500
      IF (NFLAE . LG. 3) GO TO 15
                                                                                   C1310600
      MN = C
      CALL UNFACISET . NSET . SFL X )
                                                                                    C1319700
   CALL UNPACISTIONSTIOSVC)
                                                                                   C1 31 2800
      1F (NSET . EG. 0) GO TC 5000
                                                                                   C1 31 0900
                                                                                   C1311000
      CO IE NAMI . NSET
      . : SETINSET . I - NN )
                                                                                   C1211100
      IFLX = C
                                                                                   C1311200
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IF (CTAIN(N.STI.NSTI)) GO TO 19
                                                                             C131130C
                                                                             C1311400
      IFLX = 1
                                                                             C1311500
   IS CCATIALE
      IF IFLE HUDAL VECTORS AND TENSORS FIXED IN
                                                                             C1311600
C
       BCDY N MUST DE TRANSFERMED
                                                                             C1311700
C
      CCMPLTE DEFURMED OF VECTOR AND INERTIA TENSOR BUDY N FIXED FRAME C1211800
C
      IF (. NOT . LEGUT GO TC 1000
                                                                             C1211900
      FRINT CEE.N
                                                                             C1312000
                                                                             01312100
      FRINT acs
 1000 CONTINUE
                                                                             C1312200
      CO 17 1=1.3
                                                                             C1 31 2 300
      (A(I.N) = CAC(I.N)
                                                                             (1312400
      CO 17 J=1.3
                                                                             C1212500
                                                                       1
   17 x1(1.J.A) = XIC(1.J.N)
                                                                             C1312600
      IF ( . NUT . LEQUI GO TC 1001
                                                                             C1312700
      PHINT .... N.N
                                                                             C1312800
      FRINT 221. N.N
                                                                             C1212900
      FRINT 205
                                                                             C1213000
 1001 CENTINUE
                                                                             C1313100
      SFRMA = SFRM(N)
                                                                             C1213200
      CO IE M=1. SF XMN
                                                                             C1213300
                                                                             C1313400
      PN = PN+1
      CALL SCL V(THA(NFER+MN) .FLA(1.MN) . TEM)
                                                                             C1 21 3500
      CALL VECADOLCA(I.A).TEA.CA(I.A))
                                                                             C1213600
      CALL SCLE(THA(NFER+MN).FLE(1.1.MN).TEMI)
                                                                             C1213700
                                                                             C1 31 3800
      CALL CYACDEXICI.I.NI.TEMI.XICI.I.NII
      IF ( . MLT . LE QU ) GU TE 1982
                                                                             CI 31 3900
                                                                             C1 31 4000
      AFRE & AFEHONN
      FRINT ZIC. N.N.NF X. MN
                                                                             C1314100
      FRINT 217. N.N.NF XP. MN
                                                                             00541613
                                                                             C1214300
      FRINT 2CE
 1002 CONTINUE
                                                                             C1214400
      IF ( IFL . E G . I ) GO TC 20
                                                                             C1214500
      CALL VECTEN(FLA(1.PN). XPC(1.1.N).FLAC(1.4N))
                                                                             C1214600
      (ALL VECTHNIFLOII .PN) . XPC(1.1.4) .FLUC(1.4N)
                                                                             C1214700
      IF (.AJT.LEGU) GO TC 1203
                                                                             C1214800
      FRINT 216. MN.N. MN. (FLAC(1.PN).1-1.J)
                                                                             C131490C
      C1215000
      FRINT 265
                                                                             C1215100
 ICCS CONTINUE
                                                                             01315200
   20 CONTINUE
                                                                             C1315300
   IE CENTINUE
                                                                             C1315400
      IF ( . . CT . LE GU ) GO 1C 10C4
                                                                             C1315501
      PHINT 223. N. (CA(I.N). [= 1.2)
                                                                             C1315e00
                                                                             C1215700
      FRINT 265
      FRINT 224.
                  (x1(1.1.8).1=1.3)
                                                                             C1315800
      PRINT 245. N. (X1(2.1.N).141.3)
                                                                             C1 21 5900
      FRINT 224.
                  (×1(3.1.~).1=1.3)
                                                                             C1316000
 1004 CONTINUE
                                                                             (1316100
  IF CONTINUE
                                                                             01316200
 SOCC CUATIANE
                                                                             C1216300
   IS CONTINUE
                                                                             C1216400
C
                                                                             C1316500
C
                                                                             C1 31 6600
        CERTER OF MASS VECTORS
•
                                                                             C1216700
      CALL UNFACIBLE INSET. SVAT
                                                                             21316860
      IF (NEET.EU.O) GU TC 5734
                                                                             C1 31 6900
      CO 1 Jel. Nat T
                                                                             C1217000
      # # SET(J)
                                                                             C1 31 71 00
      IF (. AJT. RBLU(K)) IL TO I
                                                                             C1217200
```

```
CALL VECTEN (CA(1.K).XPC(1.1.K).CAC(1.K))
                                                                             C1217300
      IF (LEGJ) PHINT 201. K.K.K. (CAC(1.K). 1=1.3)
                                                                             C1217400
    I CONTINUE
                                                                             C1317500
 5334 CONTINUE
                                                                             (1317600
      IF (LEGUIFHINT 202
                                                                             C1317700
C
                                                                             C1317800
C
        INENTIA TENSORS
                                                                             C1317900
      CALL UNPACISET . NSET . SVI)
                                                                             C1 31 8000
      IF (NSET.EU.D) GO TC 5035
                                                                             C1318100
      CO IC J=1.NSET
                                                                             C1318200
                                                                             C1218300
      (ALL TENTHN (XI(1.1.K).APC(1.1.K).XIC(1.1.K))
                                                                             C1318400
      IF (LEGJ) FHINT 203.
                                  (x(C(1.1.K).1=1.3)
                                                                             C1318500
      IF (LEGU) FRINT 204. K.K.K.K.(XIC(2.1.K). [=1.3)
                                                                             C131 H600
      IF (LEGUJFHINT 203.
                                  (XIC(3.1.K).1=1.3)
                                                                             C1316700
      IF (LEGU) FRINT 205
                                                                             C1318800
   IC CONTINUE
                                                                             C1318900
 SOJE CONTINUE
                                                                             C1319000
      IF ILEQUIFRINT 202
                                                                             C1319100
                                                                             C1319200
                                                                             C131930C
C
        PIAGE VECTORS
C
      COMPLT INERTIAL POSITION OF CENTER OF MASS OF BODY I
                                                                             C1319400
      CO 14 [=1.4
                                                                             01314500
   14 (8(1.1) = CON(1)
                                                                             01319600
      IF (LEJU) FRINT 214.(CH(1.1).1=1.J)
                                                                             C1 31 9700
      IF (SCF(NEL).EQ.O) GL TO EC42
                                                                             C1319800
      ITERPISSEF (NUL)
                                                                             C1319900
      ITER+2=ITEHMI+2-PCCA(NEL)
                                                                             C1320000
      DO 13 MEITERMI.ITERMS
                                                                             011220120
      CALL SCLV(THA(N).CF(1.W).TEN)
                                                                             01320200
      (ALL VECADDICALI.I).TEP. (8(1.1))
                                                                             (1320300
      IF ILEGUIPAINT 215. ..
                                                                             C1 32 04 00
   12 CENTINUE
                                                                             C1320500
 SOAZ CONTINUE
                                                                             C1 32 0600
      CALL UNPACISET . NSET . SVET
                                                                             01320700
      # (NSET.EQ.0) GO TC 5036
                                                                             C1 320830
      CO 2 JEI.NSET
                                                                             (1320900
                                                                             00015612
      * * SETIAL
      JJ = JCCALK)
                                                                             001155110
      CALL VECTHN (CS(1.K).XFC(1.1.JJ).CBC(1.K))
                                                                             01321200
      IFILEQUIFRINT 206. K.JJ. .. (CBC(1.K).i=1.J)
                                                                             01321300
    2 COATIANS
                                                                             01321400
 5236 CUNTINUE
                                                                             C1 22 1500
      IFILEGUIFAINT 202
                                                                             C1 *21 coc
C
                                                                             01321700
C
       FREE CECHDINATE VECTORS
                                                                             C1321800
      IF (NEVJ. EG. 0) 40 1C 5927
                                                                             01321900
      CO 3 Jalinava
                                                                             C132200C
      . . . . . . . . .
                                                                             01322100
  " IF (FCCA(#1.66.3) 66 TO 4
                                                                            C1322200
      CALL VECTAN (UFIL .M+1) . X+C(1.1.FCJh(M+1)) . QFC(1.M+1))
                                                                            C1 32 2 30 C
      CALL VECTOS (GFC(1.M+1).CFC(1.M-1).GFC(1.M))
                                                                             C132240C
      CALL VECAMM (UFC(1.M))
      IF (LEGUINI = W-I
                                                                            01322400
      IF (LEJUINZ . Mel
                                                                            C1322700
      IF (LE JU ) FRINT ICE. M.M2. ... (QFC(1.4). (=1.5)
                                                                            01322400
                                                                            C1322900
                                                                             C1323000
    4 (ALL VECTON (OF(1.W).XMC(1.1.FCJN(M)).JFC(1.M))
                                                                            C13241CO
      IFILEQUIPHINT 207. M.FCCA(M).4.(FC(I.M).IMI.JMI.J)
                                                                            00262612
    2 CCATIANE
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EDST CONTINUE
                                                                               C132330C
       IF (LEGU )FRINT 202
                                                                               C1323400
C
                                                                               C1 32 J500
        LOCKEC COURCINATE VECTORS
C
                                                                               C1 32 MOC
      IF (NEVP . EQ. 0) GO TC 5038
                                                                               C1 32 3700
      CO 5 J=1.NSVP
                                                                               C132360C
       L = SVP(J)
                                                                               01223930
       IFILCONILI.GE.OI GL TO e
                                                                               C1324000
       * # -LCCM(L)
                                                                               C1 724100
      CALL VECTOS (GFC(1.M).GFC(1.M+1).GLC(1.L1)
                                                                               $1324200
       CALL VECAMM (QLC(1.L))
                                                                               C1 32 4 300
       IF (L FQU 191 a Mel
                                                                               C1324400
       IFILEGUIPHINT 209. L.M.MI. (QLC(I.L).[=1.5)
                                                                               C1324500
       60 TC 5
                                                                               C1324600
    E CALL VI. AN (QL(1.L).XPC(1.1.LCJN(L)).GLC(1.L))
                                                                               C1324700
       IF (LEGUI PRINT 210. L.LCON(L).L.(GLC(I.L).I=1.J)
                                                                               C1324800
     E CENTINUE
                                                                               C1324900
 ED 36 CONTINUE
                                                                               C1325000
       IF (LEGUIFRINT 202
                                                                               C1323100
E.
                                                                               C1325200
C
       PCINT MAS . POSITION
                                                                               (1225300
      CALL UNPACISET . NSET . SLI
                                                                               C1325400
       IF (NSET .EQ. 0) GO 10 5324
                                                                               C1225500
      CO 9 KK=1 . NSE T
                                                                               01329600
      K & SETTAKE
                                                                               C1325700
      CO 11 1-1.3
                                                                               01325800
   11 TE+(1) = CA(1.K)
                                                                               C1 325900
       INTESSE (K)
                                                                               01326000
       IT IS INI . Z-PEUNIKI
                                                                               01326100
      CO 12 Maint. ITT
                                                                               01326205
      IF (LEGUIFRINT 212 . K.K. ..
                                                                               C1326305
      CO 12 1=1.3
                                                                               C1326400
   1 = TEM(1) = TEM(1) + THA(+)+QF(1.4)
                                                                               C132650C
      CALL VECTOR (TEM. XPL(1.1.K).CAL(1.K))
                                                                               01226400
       IF (LEGUIPHINT 213. K.K.K.(CAC(I.K). 1=1.3)
                                                                               C1226700
    S CONTINUE
                                                                               C1 326800
 2035 CONTINUE
                                                                               C1 326 900
                                                                               01327000
         INCULAR MUMENTUR OFEEL
                                                                               C1227100
      CALL UNPACISET . NSET . SVM)
                                                                               C1327200
       IF INSET . EU . OJ UU TE 5040
                                                                               C1 3/ 7 100
      ED 7 JJEI.NSET
                                                                               C1 32 7400
      J = 1811.31
                                                                               C1 32 7500
      CALL VECTOR (MM(1.J).XMC(1.1.MJ(J)).MMC(1.J))
                                                                               C1 32 7 coc
    7 CCATINUE
                                                                               CA 32 7 70C
 STAC CONTINUE
                                                                               01227600
       IF ( . NOT . LEGUI RETLAN
                                                                               C 1 32 7900
       IFINSET.EG.O. GO TC 5741
                                                                               01 22 4000
      Tacelelate 8 00
                                                                               C132#100
       1 . 1511441
                                                                               01328200
      FRINT ... J.MJ(J).J.(HM((1.J).[=1.2)
                                                                               C1 32 # 300
    F CENTINUE
                                                                               C1 32 840C
 SOAT CONTINUE
                                                                               01328500
      PRINT 202
                                                                               0.032 #600
C
                                                                               C1328700
                                                                               00885510
  200 FORMAT ("1 SUBRULTINE TRANSO ENTERED ".2(/))
                                                                               C1 32890C
  201 FGAMAT (* CAC(*,12.*) = xMC(*,12.*) * (4(*,12.*) = *,3017.4)
                                                                              000088810
  202 FORMAT(3(/))
                                                                              01229100
  202 FCEMAT (44x. 3017.6)
                                                                               01229200
```

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```
204 FORMAT (* XIC(*,12,*) = XMC(*,12,*) * XI(*,12,*) * XMC(*,12,*) **TC1329300
   . = ' .3017.8)
205 FCRMAT ( ' ')
                                                                       C1329500
206 FORMAT (' CUC(',12,') = XMC(',12,') * CU(',12,') = ',3017.8)
                                                                       C1329600
207 FORMAT (' QFC(',12,') = XMC(',12,') * QF(',12,') = ',3017.8)
                                                                       C1 329700
208 FORMAT (* QFC(*,12,*) = NCFM(QFC(*,12,*) x QFC(*,12,*)) = *,3017.01329800
                                                                       01329900
   * F)
205 FORMAT ( ' GLC(',12,') = NORM(GFC(',12,') X GFC(',12,')) = ',3017.01330000
                                                                       C133010C
  4+1
                                                                        C1330200
210 FORMAT (' QLC(', IZ, ') = XMC(', IZ, ') * <math>QL(', IZ, ') = ', 3D17.8)
211 FORMAT (' HMC(',12,') = XMC(',12,') * HM(',12,') = ',12x,3017.8) C133030C
212 FORMAT (' CA(',12,') = (A(',12,') + THA(',12,')*UF(',12,') ')
                                                                       C133040C
213 FORMAT (35X, ' CAC(',12,') = XMC(',12,')*CA(',12,') = ',3D17.6./) C1330500
214 FORMAT (' CB( 1) = '.3017.8)
                                                                       C1 33060C
215 FCRMAT (' CH( 1) = CH( 1) + THA(',12,')*UF(',12,') ')
                                                                       C1330700
216 FURMAT (20x, ' CA(',12,') = CA(',12,') + THA(',72,')*FLA(',12,')')C1330800
217 FORMAT (30x. 1
                  x1(',12,') = x1(',12,') + THA(',12,')*FLE(',12,')')C1330900
              (' FLAC(',12,') = XMC(',12,')*FLA(',12,') = ',3D12.5) (1331000
216 FORMAT
219 FORMAT (* FLGC(*,12,*) = xMC(*,12,*)*FLG(*,12,*) = *,3D12.5)
                                                                       01331100
                                                                       (1331200
22C FORMAT (23x,' CA(',12,') = CAJ(',12,') ')
221 FORMAT (30x. *
                  xi(',i2,') = xij(',i2,') ')
                                                                       C1331300
223 FORMAT (30x. ' CA('.12.') = '.3012.5)
                                                                       C133140C
224 FORMAT (40X. JU12.5)
                                                                       01 331500
225 FURMAT (30x.' x1(',12.') = '.3012.5)
                                                                       C133160C
226 FORMAT (//.25x. FLEXIELE ECDY PARAMETERS FOR BUDY 1.13)
                                                                       C1 331700
                                                                       C1331H00
    SE THEN
    FNC
                                                                       C1331900
```

```
C
                                                                        C1400C00
                                                                        C1403100
     SUBHCUTINE MATE
      USEC TO COMPUTE ALL LINER AND ANGULAR VELOCITY VECTUPS REQUIRED
c
                                                                       C14202C0
                                                                        C1400300
        RCMC(1.K) = FCH ECDY K HIGID- ANGULAR VELUCITY OF BODY K FIXED (1499400
C
                          AXES RELATIVE TO BODY JCCN(K) FIXED AXES:
C
                                                                        C1420500
C
                     FOR BODY K POINT MASS- LINEAR VELOCITY OF FUINT MASCI400600
                          REALATIVE TO AXES FIXED AT HINGE POINT K-1
C
                                                                       C1400700
        CCMC(1.K) = FOR BODY K HIGID- ANGULAR VELUCITY OF BODY K FIXED C1400800
C
                          AXES RELATIVE TO FRAME OF COMPUTATION
C
                                                                        C1400900
                                                                        C1401000
                     FCH FODY & PCINT MASS- EQUALS ROMC(I.K)
C
        FCMC(1.K) = FCH BODY K HIGID- ANGULAH VELUCITY UF BODY K FIXED C1491100
C
                          AXES RELATIVE TO INERTIAL FRAME
                                                                        C14C1200
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                    FOR BODY & PEINT MASS- EQUALS RUMC(1.K)
                                                                        C1401300
        DCMC(I.K) = SUM OF INERTIAL DERIVATIVES(FIRST) OF FREE VECTORS C1401400
C
C
                    AT HINGE FOINT K-1
     IMPLICIT REAL *= (A-+.U-Z.1)
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                                                                        C1401700
C
                                                                        C1401800
C
     LOCICAL FG1. FG2. FG3. FG4. F35. INERF. HBLU. LEQU. LINIT(1)
                                                                        C1401900
                                                                        C1402000
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                     LTHANY . LEATE . LXUY . LETA
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     INTEGER
                                   . CT4 . CT5 . FCCN . PCCN .
                    . CT2 . CT3
                                                                       C14026CC
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                                   . SFRUUM, SFK
     . SCHOUN. SCH . SCHOUN. SCH
                                                    . SFR . SG
                                                                    . (1402700
```

```
• 51
           , SIG , SIXDUM, SIX , SKDUM , SK , SL , SLK , C140280C
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           , SMCDUM, SMC , SMV , SJK , SPIDUM, SPI , SQF , C1402900
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     * SCL
           . SR . SSCN . SEIX . SVA . SVB . SVD . SVI
                   . 500 . SXN
                                          . TURG
     . SVM
           . SVP
                                  . SXT
                                                 . SMAL
                                                         . SEU
                                                                   C1403100
                                  . SFXM . NMCDS . SFCC . SCC
     * SC
            . SCG
                   . NFLX8 . SFLX
                                                                    C1403200
     4 [INIT(1)
                   . IZINIT(1)
                                  . SD
                                                                    C1403300
C
                                                                    C1433400
                                                                    C1403500
C
                                                                    C1403600
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                                                                    C1403700
     * ANGC (33)
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     * FLQ (3,20) . FLE (3,3,20), FLH (3,3,20).
                                                                    C1403900
     * THACO (33) , YMCD (3.2.11). HINIT (1) . RZINIT(1)
                                                                    C1404000
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                                                                    C1404100
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                                                                   C1404200
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                    LIRANV . LRATE . LXDY . LETA . LTORQU .
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                                                                   C1 404600
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                                                                   (1405900
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                                  . SR
                                                 . SSCN
    * SCL
                                                                   C1406000
                                                 . SVD
     . SSIX
                   . SVA
                                  . SVB
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                                                         (33)
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                                                 . SVQ
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                   . SFLX
                                                                . 01406500
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                                                 . NMODS
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C
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                                                                    C1406800
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                                                . SCR (9)
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                                                                . C1497000
                   . SFK
                                  . SIXDUM
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     . SFKCUM
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                                                                . 01437100
                   . SK
    . SKOLM
                           (5)
                                  . SPIDUM
                                                · SPI
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                   . SMC
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     CCHMIN /FEAL/
                                                                   C14C7600
                           (3,10) . CLM (10) . CGMC (3,11) . (3,11) . ETM (33) . FLMC (3,11) .
           (3.10) . CAC
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                                  . HM
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                           (3.11) . PLM
                                         (10) . OF
                                                         (3.33) .
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* FLIRC (3.10) , FLCRC (3.10) , FLAC (3.20) , FLQC (3.20) , C1408700
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* FLCN (20) , ZETA (20) , FCF (3.3.40), FCK (3.40) , (1408800
     . TIMEND
                                                                         C1408900
C
                                                                         C1409000
                                                                         C1409100
0
     CCHMEN /HEALZ/
                                                                         C1409200
     * CBDLM (1.3) . CE (3.10) . CdCoUM(1.3) . CdC
                                                              (3.10) .
                                                                        C140930C
     * XMCCLM(1.1.9) , XMC (2.3.13), CdN(3)
                                                                         C14094C0
C
                                                                         C1409500
C
                                                                         C1409600
     EGUINALENCE (ETM(1). THACC(1))
                                            . (XMN(1.1). ANGD(1))
                                                                         C14097C0
                                            .(XMN(1.6).CNF(1.1)) .
                  (XMN(1.3).YMCD(1.1.1))
                                            .(XMN(1.6).CNF(1.1))
                                                                         C1409800
                  (XMN(1.8).ETIC(1.1))
                                                                        C1409900
                  (FLB(1.1).FLG(1.1))
                                            .(FLE(1.1.1).FLC(1.1.1)).
                                                                        C1410000
     ٠
                  (FLH(1.1.1).FLJ(1.1.1))
                                                                         C141010C
                                            .(CA(1.1).RINIT(1))
     .
                  (FGI.LINIT(1))
                                                                         C1410200
                                           .(AWGRK(1).IINIT(1))
                  (CHOUM(1.1).FZINIT(1))
                                                                         C1410300
                  (SCNOLN, IZINIT(1))
                                                                         C141 C400
     CINENSICN X1(3).X2(3)
                                                                         C1410500
     CINENSILA TEMI(33).TEM2(33)
                                                                         C141060C
      REAL+8 EFUNC(33). ECCMC(33). EROMC(33). EDUMC(33)
                                                                         C1410700
      INTEGER SET (10)
                                                                         C141 C80C
     LOCICAL CTAIN
                                                                         C141090C
                                                                         C1411000
     LSE SINGLE DIMENSION ARRAYS WHEN ADVANTAGEDUS TO INCREASE
                                                                         C1411100
C
      COMPLIATION SPEED
                                                                         C1411200
      EQUIVALENCE(FCMC(1.1).TEMI(1)). (CCMC(1.1).TEM2(1))
                                                                         C1411300
     EQUIVALENCE (EFONC(1).FCMC(1.1)). (ECJMC(1).COMC(1.1)).
                                                                         C1411400
                  (ERCMC(1).FCMC(1.1)). (EDCMC(1).DGMC(1.1))
                                                                         C1411500
                                                                         C1411600
C
     EGUIVALENCE (LRATE.LEGL)
                                                                         C1411700
C
                                                                         C141180C
                                                                         C1411900
     IF (LEGU)PHINT 200
                                                                         C141200C
     IF (.NUT.LEGU) GO TO 1000
                                                                         2012100
      IF (INERF) GU TO 33
                                                                         C1412200
      FRINT LOI
                                                                         C141230C
     CO TC 34
                                                                         C1412400
   33 FRINT aca
                                                                         C141250C
  34 CONTINUL
                                                                         C1412600
     EVALUTE RELATIVE VELOCITY VECTURS
                                                                         C1412700
 1000 CENTINUE
                                                                         C1412BC0
                                                                         C1412900
      w = 1
      DO 1 K= 1.NB1
                                                                         C1413000
      IF (K.EJ.1) GC TO 2
                                                                         C1413100
                                                                         C141320C
      N = N+3-FCUN(K-1)
    E CENTINUE
                                                                         C1 41 330C
      IK1 = 2 * K-3
                                                                         C1413400
                                                                         C1413500
      CC 31 I=1.3
      IK = 1K1+1
                                                                         C1413600
   31 ERCMC(IK) = 0.00
                                                                         C141370C
      IF (LEGU) PRINT 221 . K
                                                                         C1413800
      IK = IK1 +'1
                                                                         C1413900
      ITERN = N+2-PCCN(K)
                                                                         C1414000
      IF (M.GT.ITEHM) GO TO 1
                                                                         C1414100
                                                                         C1414200
      CO 3 MM=M.ITERM
      (ALL SCL V(THAD (MM) . OFC(1 . MM) . XI)
                                                                         C1414300
      (ALL VECADD(X1.ERCHC(IK).ERCHC(IK))
                                                                         C141440C
      IF (LEGUIPHINT 205. K.K.M.MM
                                                                         C1414500
                                                                         C1414600
    3 CENTINUL
                                                                         C1414700
    1 CONTINUE
```

```
IF (.NOT.LEGO) GO TO 1901
                                                                            C1414800
      FRINT 214
                                                                            C1414900
      CC 25 K=1.Nd1
                                                                            C1415CCC
   25 FRINT 215, K. (ROMC(J.K).J=1.3)
                                                                            C1415100
                                                                            C1415200
      FRINT 214
 1001 CONTINUE
                                                                            C1415300
C
                                                                            C1415400
        EVALUATE ANGULAR VELCCITY BODY K TO INERTIAL AND COMPUTING FRANECIAIS500
C
C
                                                                           C14156C0
C
      TAKE CARE UF RIGIE BODY ANGULAR RATES
                                                                            C1415700
      CALL UNPACISET. NSET. SR)
                                                                            C1415800
      CC 7
            1=1.3
                                                                            C14159CO
    7 FCMC(1.1) = RGMC(1.1)
                                                                            C141600C
      IF (LEGUIFAINT 219
                                                                            C1416100
      ASETAL = NSET - 1
                                                                            C141620C
      IF (NSETMI.EU.O) GC TO 5042
                                                                            C1416300
      DG 8 JJ= 1.NSETM1
                                                                            C141640C
      4 = NSETNI - (JJ-1)
                                                                            C1416500
      K = SET(J)
                                                                            C1416600
      CALL VECADDIFUNC(1.JCCN(K)).RCMC(1.K).FCMC(1.K))
                                                                           C141670C
      IF (LEQUIJK = JCCN(K)
                                                                            C141680C
      IF (LEJUJFHINT 209. K.JK.K
                                                                           C1416900
    E CONTINUE
                                                                            C1417000
ED42 CONTINUE
                                                                            C1 41 71 CO
                                                                            C1417200
      IF (INEMF) WU TO II
                                                                            C1417300
      CC 9 1=1.3
                                                                            C1417400
    S ECCMC(1) = C.DC
      IF (LEJU) PRINT 214
                                                                            C1417500
      IF (LEGUIFRINT 222
                                                                            C141 760C
      ASETMI = NSET - 1
                                                                            C1417700
      IF (NEETMI.EU.O) GU TO 5043
                                                                            C1417800
      CO 1 C JJ = 1 . NSETM1
                                                                            C1417900
      # = NSETMI - ( JJ - 1 )
                                                                           C1418000
      K = 527(J)
                                                                           (1418100
      CALL VECADDICUMC(1.JCCN(K)).FOMC(1.K).COMC(1.K))
                                                                           C141820C
      IF (LEJU) JK = JCCN(K)
                                                                           C1418300
      IF (LEGU)FRINT 210. K.JK.K
                                                                           C1418400
   1 C CONTINUE
                                                                            C1418500
5343 CONTINUE
                                                                            C1418600
      IF (LEGU)PRINT 214
                                                                           C1418700
      CU TC LE
                                                                            C1418800
C
                                                                           C1418900
      CCMC = FEME VIA EGUIVALENCE FOR INERTIAL COMPUTING FRAME
                                                                           C1419000
   11 ITER# = 3 . NOOD
                                                                           C1419100
      CC 12 1 = 1. ITERM
                                                                           C1419200
   13 TEN2(1) = TEM1(1)
                                                                           C1419300
      IF (. NOT . LEGU) GO TC 1902
                                                                           C1419400
      FRINT 214
                                                                           C141950C
      CC 24 Kal.NBUD
                                                                           C1419600
   26 PRINT ZEC. K.K
                                                                           C14197CO
      FRINT 214
                                                                           C1419800
1002 CONTINUE
                                                                           C1 41 9900
   12 CONTINUE
                                                                           C1420000
C
                                                                           C1420100
C
      TAKE CAME OF LINEAR OSCILLATORS AND CENTER OF MASS MOTION
                                                                           C1420200
      CALL UNPAC(SET.NSET.SL)
                                                                           C1420300
      IF (NEET.EU.O) GU TC 50CC
                                                                           C1420400
                                                                           C1420500
      CO 23 J=1.NSET
      K = SET(J)
                                                                           C1420600
      IF (LEGU) PRINT 223. K.JCCN(K)
                                                                           C1 42 070C
```

```
IF (LEGUI PRINT 224, K.JCCN(K)
                                                                           C142CE00
      CO 6 1=1.3
                                                                            C1420900
      FOMC((.K) = FONC((.JCCN(K))
                                                                            (1421000
    e CCMC(1.K) = CUMC(1.JCUN(+))
                                                                           C142110C
   23 CENTINUE
                                                                           C1421200
 SOCC CONTINUE
                                                                           C1421300
      FCMC(I.NEI) = HOMC(I.NBI)
                                                                            (1421400
   IS CCAC(I.NEI) = HOMC(I.NEI)
                                                                           C1421500
      IF (LEGU) PRINT 2CE. NHI.NEL.NJI
                                                                           C1421600
C
                                                                           C1421700
      IF ( . NOT . LEGU) GO TC 1003
                                                                           C1421800
      CO 26 K=1.NH1
                                                                           C1421900
   26 FRINT 217. K. (COMC(J.K). = 1.3) .K. (FCMC(J.K). J=1.3)
                                                                           C1422000
      FRINT 214
                                                                           C1422100
 1003 CONTINUE
                                                                           C1422200
         EVALUTE COMPONENTS OF ACCELERATION ASSOCIATED WITH COOFDINATE C1422400
C
C
          FRAME RUTATION
C
                                                                           C1422600
      IF (CT4.NE.1) GO TO 15
      CO 15 #=1.NU1
                                                                           C1422300
      IK = 3 .K-5
                                                                           C1422900
      CO 14 I=1.5
                                                                           01423000
      IK = IK+1
                                                                           C1423100
   14 EDCMC(1K) = 0.00
                                                                           C1423200
      IF (LEGU) FRINT 212. K
                                                                           C1 42 330C
   15 CONTINUE
                                                                           C14234C0
C
                                                                           C1 42 3500
      CYCLE THEOUGH ALL ECDIES
                                                                           C142360C
                                                                           C1423700
      h = 1
      CO 16 K=1.NHCD
                                                                           C1423800
      1K1 = 3+K-3
                                                                           C1423900
      IF (LEGUJFHINT 203
                                                                           C1424000
      IF (K.EJ.1) GO TO 17
                                                                           C1424100
      w = ++3-FCON(K-1)
                                                                           C1424200
   17 1F ( . NUT . FOLO(K)) 60 TO 16
                                                                           C1424300
      CO 21 1=1.3
                                                                           C1424400
      IK = IK1+1
                                                                           C1424500
  21 EDCMC(IK) = 0.00
                                                                           C1424600
      IF (LEQU)FRINT 212. K
      TAKE CARE OF COMPONENT DIE TO ROTATION OF FRAME & RELATIVE TO INERCIAZABOO
                                                                           C1424900
      CYCLE THROUGH FREE COORDINATE VECTORS AT HINSE POINT K-1
                                                                           C1425000
      IK = IK1 + 1
      *** = # + 2 - PCUN(K)
                                                                           C142510C
      1F (M.GT.MMM) GD TC 5044
                                                                           C142520C
      CO 16 MM= M.MMM
                                                                           C1425300
      MF = FCLN(MM)
                                                                           C142540C
      IF (MF.LT.0) GO TO 18
                                                                           C1425500
      IF (MF.EG.0) GO TJ 16
                                                                           C1425600
      (ALL VECTUS (FCMC(1.MF).GFC(1.MM).X1)
                                                                           C14257CO
                                                                           C14258C0
      (ALL SCLV(THAD(MM).X1.X1)
      CALL VECADD(ECCMC(IK).X1.EDONC(IK))
                                                                           C1425900
      IF (LEGUJEHINT 213. K.K.MA.MF.MA
                                                                           C142600C
      CO TC 16
                                                                           C1426100
  16 MF = FCCN(MM-1)
                                                                           C1426200
                                                                           C1426300
      M1 = MM-1
                                                                           C14264CC
     CALL SCLV(THAD(MI).UFC(1.MI).X1)
      IF (MF.EG.0) GO TO 4
                                                                           C1426500
      (ALL VECADD(FOMC(1.MF).X1.X1)
                                                                           C142660C
    4 CONTINUE
                                                                           C1426700
```

```
CALL VECTOS (X1.0FC(1.FM), X2)
                                                                            C1426800
      (ALL SCLV(THAD(MM).x2.x2)
                                                                             (1426900
      CALL VECADDIEDCMC(IK). X2.EDCMC(IK))
                                                                            C1427000
      IF (MF.= G.0) GO TO 5
                                                                             (1427100
      IF (LEGU) FRINT 21c. K.K. N. D. DF. MI. MI. PM
                                                                             C1427200
                                                                            C1427300
      CC TC 16
    & CONTINUE
                                                                             C1427400
      IF (LEGU)PHINT 204. K.K.MP. PI.MI.MM
                                                                            C1427500
 5044 CENTINUE
                                                                            C1427600
   16 CONTINUE
                                                                            C1427700
      IF ( . NOT . LE UU ) RETURN
                                                                            C1427800
      FRINT 214
                                                                            C1427900
      CC 25 F=1.NB1
                                                                            (1428000
   29 PRINT 227. M. (DCMC(J.M). =1.3)
                                                                            00185413
C
                                                                            C1428200
                                                                            C1428300
  200 FORMAT (' SUBROLTINE RATE ENTERED ')
201 FORMAT (/.' COMPUTING FRAME (5 800Y 1 *./)
                                                                            C1428400
                                                                            C1428500
  202 FORMAT ( /. * COMPUTING FRAME IS INERTIALLY FIXED "./)
                                                                            C142 F600
  203 FORMAT ( ' ')
  204 FORMAT (* DCMC(*,12,*) = DCMC(*,12,*) + THAD(*,12,*)*TFAC(*,12,*)C1428800
     **QFC(',12.') x QFC(',12.'). ')
                                                                            C1428900
  205 FORMAT (' HCMC(',12,') = RCMC(',12,') + THAD(',12,')*GFC(',12,') C1429000
    ..,
                                                                            C14291C0
  206 FORMAT (' FCMC(', [2,') = CCMC(', [2,') = RGMC(', [2,') ')
                                                                            C1429200
  205 FORMAT ( * FEMC( *.12.*) = FEMC( *.12.*) + MEMC( *.12.*) *)
                                                                            (1429300
  210 FORMAT (' LUMC(',12,') = CCMC(',12,') + RUMC(',12.') ')
  212 FORMAT (' DCMC('.12.') = 0 ')
                                                                            C1429500
  213 FORMAT (' DOMC('.12.') = D(MC('.12.') + THAD('.12.')*(FCMC('.12.'(1429600
     *) * GFC(',12,'))')
                                                                            C1429700
  214 FCFMAT(2(/))
                                                                            C14298CO
  215 FORMAT (' HCMC('.12.') = '.3017.8)
                                                                            C142990C
  216 FURMAT (' DCMC(',12,') = DCMC(',12,') + THAD(',12,')+((FCMC(',12,C1430000
     *') + THAD(',12,')*GFC(',12,')) x GFC(',12,'))')
                                                                            C1430100
  217 FORMAT (' CCMC('.12.') = '.3017.8.' FUNC('.12.') = '.3017.8)
                                                                            C143020C
  219 FORMAT ( .
                FCMC( 1) = FCMC( 1) ')
                                                                            C14303CC
  220 FORMAT ( .
                LCMC(',12,') = F(MC(',12,') ')
                                                                            C1430400
  221 FORMAT ( .
                RCMC('.12.') = 0 ')
                                                                            C1430500
  222 FORMAT ( .
                CCMC( 1) = C ')
                                                                            C1430600
  223 FORMAT ( .
                 FCMC('.12.') = FCMC('.12.') ')
                                                                            C1430700
  224 FORMAT ( .
                CCMC('.12.') = CCMC('.12.') ')
                                                                            C1430800
  227 FORMAT ( ' DOMC( '.12. ') = '.3017.8)
                                                                            C1430900
      RETURN
                                                                            C1431000
      ENC
                                                                            C1431100
```

```
C1 500000
C
      SUERCLTINE XDY
                                                                          C1520100
C
        CCMPUTES VALUES OF VECTORS AND DYADS USED TO DEFINE SYSTEM INERT (1500200
C
          TENSER MATRIX
                                                                          C1500300
C
                                                                          C1500400
C
     LET:
           GAM(I.KL) = COMPONENTS OF VECTOR FRUM HINGE FOINT K-1 TO THE (150600
C
C
                       CENTER CF MASS OF EUDY LAMBA WHERE
                                                                          C150C700
(
                                KL = KTO(NOOD+1.K-1.LAMBA)
                                                                          CISOCACO
       xDIC(1,J.KI) = CEMPONENTS OF TENSOR OF HANK TWO IN ROW K, CEL I C1500900
C
                       CF THE SYSTEM MATRIX UF INERTIA TENSORS
                                                                          (1501000
```

```
BEFF
C
                                                                                  C15011C0
                                    KI = KTI(NSUD+1.K.I)
C
                                                                                  C1501200
      NOTE:
C
                                                                                  C1501300
C
           THE SYSTEM MATRIX OF INERTIA TENSORS IS SYMMETRIC THUS CALLY (1501400
           LIGER TRIANGLLAR POFTION COMPUTED
C
      IMPLICIT REAL . B(A-H.C-Z.1)
                                                                                  (1501600
                                                                                  C1501700
C
C
                                                                                  C15018C0
      LOCICAL FG1, FG2, FG3, FG4, FG5, INERF, MBLO, LEUU, LINIT(1)
                        LTEANY . LTATE , LXDY , LETA , LTORQU ,
      LCGICAL
                                                                                 C15020C0
                                                                                  C1502100
                        LOFDOT . LOCT . LANGLE . LSETUP . LSING
                                                                                 C1502200
C
                                                                                  C1502400
      INTEGER
                                                                                  C1502500
     . ANDRK . CT1 ', CT2 , CT3 , CT4 , CT5 , FCCN , PCCN ,
                                                                                 04502600
     * SCNEUM, SCN , SCRDUM, SCR , SFKDUM, SFK , SFR , SG
* SI , SIG , SIXDUM, SIX , SKDUM , SA , SL , SLK
                                                                              . (1502700
                                                                              · C1502800
              SMCDUM, SMC , SMV , SGK , SPIDUM, SPI , SGF , C1502900

SR , SSCN , SSIX , SVA , SVB , SVD , SVI , C1503000

SVP , SVG , SXM , SXT , TGHG , SMAL , SEU , C1503100

SCG , NFLXB , SFLX , SFXM , NMCDS , SFCC , SCC , C1503200
     . SMA
            . SR
     * SCL
     . SVM
     * 50
     • IINIT(1)
                     . IZINIT(1) . SO
                                                                                  C1503300
C
                                                                                  C1503400
C
                                                                                  C1503500
      REAL .d
                                                                                  C1503600
     * ANGC (33) . CNF (3.10) . ETIC (3.10) . ETIC (3.10) . C1503700

* FLO (3.20) . FLE (3.3.20). FLH (3.3.20). C1503800

* THACD (33) . YMCD (3.2.11). HINIT (1) . RZINIT(1) C1503900
C
                                                                                 CIFOACCC
                                                                                 C15C4100
     COMMON /LDEBUG/ LRUNGE . LTRNS! . LVDIV . LEGUIV . LTRAN .

LTHANV . LRATE , LXDY . LETA . LTDRGU .
                                                                                C1504200
                                                                                 C1534300
                        LCFDCT . LDCT . LANGLE . LSETUP . LSING
                                                                                  C15044C0
C
                                                                                 C1 504500
C
                                                                                  CIEO4ECC
     COMMEN /LOGIC/ Ful. FG2. Ful. Ful. Fus. INERF. HELO(10)
                                                                                 C1504700
C
                                                                                  (1504800
                                                                                 C15C4900
C
     CCMMEN /INTG/ AWORK(200) .
                                                                                  C1 505000
                                        . CTS
                                                          . CT4
                      · C12
                                                                             . 01575100
     • C11
                                        . JCCH (10) . LCCH (22)
     · C15
                       . FCGN (33)
                                                                                 C1505200
                                         · NHUD
                                                           . NCTC
                       . NE1
     . ..
             (10)
                                                                                 C1 505300
     . NEER
                      . NFKC
                                        . NERC
                                                           . NLOH
                                                                                 C15C5400
                       . ANG
                                        . NHOA
     . NAV
                                                           . NSVP
                                                                                 C15055C0
                               (11) . SC . . SFR (33)
(E5) . SIG . . SL
(10) . SGK (11) . SGF (11)
                      . FCON (11)
     . NEVE
                                                                                 (1505600
     . SC
                       . 51
                                                                                 C1505700
                     . SMA
     • SLK (33)
                                                                             . 01505800
                     . SAV
                                         · SR
                                                          . SSCN
     • SGL (11)
                                                                                 C15C590C
                                                          . SVD
     . 551>
                       . SVA
                                         . SVd
                                                                                 01506000
                                                (22)
                                                                    (33)
     · SVI
                       . SVM
                                         . SVP
                                                           . SVQ
                                                                                 C1506100
                                         . TORG (97)
                                                           . SMAL
     . SXM
            (3.10) . SXT
                                                                              . 01506200
                      . ATG
     . SEU
                                         . SC
                                                (33)
                                                          . SCG
                                                                                 01506300
                      . SFLX
                                        . SFXM (10)
                                                                              . 01506400
     . NEL XH
                                                           . AMCDS
     · SFCC
                      . SCC (10)
                                                                                  C15C35C0
C
                                                                                  C1 506600
                                                                                 C1506700
     CCMMCN /INTGZ/
                                                                                 C15068CC
     SCNDLM SCN (5) SCHDUM
SFKCLM SFK (5) SIXDUM
                                                          • SCR (9) • C15C69C0
• SIX (9) • C15070C0
     · SFKCLM
```

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. SK
                                                                        . C153710C
     . SKOLM
                             (5)
                                      . SPIDUM
                                                     . SPI (9)
                      . 5+0
     . SHCELM
                            (5)
                                                                           C15C7200
                                                                           0150.300
C
C
                                                                          C1507400
     CCMMCN /FEAL/
                                                                          C1507500
             (3.10) . CAC
                            (3.10) . CLM
                                             (10) . CCPC (3.11) . C1507600
     . ..
     • DCMC (3.11) . ETC
• GAM (3.00) . F
                                                              (3.11)
                             (3.11) . ETM
                                              (33)
                                                      . FCMC
                                                                          C1507700
                                              (3.10) . HMC
                                      . HM
                                                               (3.10)
                                                                          C1507800
                     . PHI
                                     . PLM
                                                       . GF
                                                               (3.32) .
     . HHEN
                              (2.11)
                                             (10)
                                                                          C15C7900
            (10)
                                     . QLC
     · QFC
             (3.33) . GL
                              (3.22)
                                              (3.22) . ACMC
                                                               (3.11) . (1508000
                                        THA
                                              (33)
                                                     . THAD
                                                              (33)
                                                                       . (1508100
     . T
                     . THAN
                                                                          C15082C0
     4 THAC# (10)
                             (12)
                                     . XUIC
                                              (J. J. 00) . XI
                                                               (3.3.10).
             (2.3.10). XMAS (10)
                                      . XMN
                                              IMX , (EL, LE)
                                                               (3.3.10). (1508300
     · XIC
                    . FLA
                              (3.20) . FLd
                                              (J.20) . FLC
                                                               (3.20)
                                                                       . 01508400
     . TLG
             (23)
     • FLD (3.3.20), FLJ (3.3.20), CAU (3.10) , XIU (3.3.10), FLIRC (3.10) , FLCRC (3.10) , FLAC (3.20) , FLOC (3.20) ,
                                                               (3.3.10). (1508500
                                                                          C1598600
                     . ZETA (20)
                                              (J.J.40). FCK
                                                               (3.40) .
     . FLC. (20)
                                      . FCF
                                                                          C1508700
     . TIMENO
                                                                           C1508800
                                                                          C15C8900
C
C
                                                                          C1509000
     CONMIN /HEAL Z/
                                                                          C1509100
     • CEDLM (1.3) . CH
                              (3.10) . CdCDUM(1.3) . CBC
                                                                       . 01509200
                                                               (3.10)
     . XPCCLM(1.1.9) . XMC
                            (3.3.10). CSN(3)
                                                                          C1509300
                                                                          C1509400
C
                                                                          C1509500
      EQUIVALENCE (ETM(1).THACC(1))
                                             . (XMN (1.1) . ANCO(1))
                                                                          01509600
                  (XMN(1.3).YMCO(1.1.1))
                                             . (KMN(1.6).CNF(1.1))
                                                                          C1529700
                  (XMN(1.8).ETIC(1.1))
                                             .(XMN(1.10).ETMC(1.1)) .
                                                                          CISOGRCO
                  (FLB(1.1).FLG(1.1))
                                             .(FLE(1.1.1).FLD(1.1.1)).
                                                                          (1509900
     .
                  (FLH(1.1.1).FLJ(1.1.1))
                                                                          C1 51 30C0
                  (FGI.LINIT(I))
                                             .(CA(1.1).RINIT(1))
                                                                          £1510100
                                             .(Asufk(1).IINIT(1))
                  (CHDUM(1.1).FZINIT(1))
                                                                          C1510200
                  (SCNDLM.IZIAIT(I))
                                                                          £1510300
                                                                          (15104CO
C
     INTEGER ST1(10).ST2(12).ST3(10).ST4(12)
                                                                          C1510500
     CIMENSILN TEM(3). TEMI(3,3). TEM2(3,3). TEM3(3). TEM4(3,3)
                                                                          C1510600
                                                                          C1510700
      EQUIVALENCE (LXDY . LEQU)
c
                                                                          C1510800
C
                                                                          (1510900
C
                                                                          CIELLCCO
C
                                                                          CISILICO
C
                                                                          01511200
     IF (LEGU)FRINT 228
                                                                          01511300
      IF (C14.NE.1) GO TC 20
                                                                          C15114C0
      FIRST PASS THROUGH PUT FULL SETS IN DECREASING
                                                                          C1511500
C
       CEDER CF MAGNITUCE
                                                                          C1511600
      CO 21 K=1.NBOD
                                                                          (1511700
      ST3(K) = NB1-K
                                                                          C1511800
   21 ST4(K) = NB1-K
                                                                          C15119C0
      AST3 = NEUD
                                                                          C1512000
      ASTA = NEOD
                                                                          C1512100
      60 TC 22
                                                                          C1512200
                                                                          C1512300
C
C
         SAT - THOSE ROBS OF INERTIA MATRIX. UVER TO DIAGONAL. WHICH
                                                                          C1512400
               ARE TIME VARYING AND MUST BE RECALCULATED
C
                                                                          C1512500
C
                                                                          C1512600
C
         SVO - THUSE BODIES IN WHICH BODY FIXED VECTORS AND DYACS ARE
                                                                          C15127CO
C
               TIME VARYING IN COMPUTING FRAME
                                                                          C1512800
                                                                          C1512900
   2C CALL LNPAC(ST3.NST3.SXT)
                                                                          C1 51 30 00
```

*

```
IF (LEQUIPHINT 202. SXT. ($13(1).1=1.NSTJ)
                                                                            C1513100
      (ALL UNPACISTA .NST4.SVD)
                                                                            C1513200
      IF (LEGU)FRINT 203. SVD.(ST4(1).1=1.NST4)
                                                                            C1513300
C
                                                                            C1513400
C
      COMPLIE VECTORS FROM HINCE FOINT K-1 TO DODY LAMEA CENTER OF MASS C1513500
C
            SICHE UPPER TRIANGLLAR
C
C
      AFTER FIRST PASS RECOMPUTE ONLY THOSE WAM VECTURS WHICH ARE TIME VC1513800
C
   22 CONTINUE
                                                                            C15140C0
      IF(NST4.EQ.0) GO TO 5045
                                                                            C1514100
      CO 3 LP=1.NST4
                                                                            C1514200
      L = ST4(LP)
                                                                            (1514300
      KLL = KIC(NB1.L-1.L)
                                                                            C1514400
      CO 4 1=1.3
                                                                            C1514500
    4 CAM(I.KLL) = CAC(I.L)
                                                                            CISIACCO
      IF (LEGU) FRINT 229
                                                                            C15147C0
      IF (LEGUILI = L-1
                                                                            C151480C
      IF (LEGUJPHINT 204. KLL.LI.L.L
                                                                            C1514900
      LL = L
                                                                            C1515000
    E # = JCCN(LL)
                                                                            C1515100
      IF (K.EJ.C) 60 TO 3
                                                                            C151520C
      KL = KTC(NU1.K-1.L)
                                                                            C1515300
      CALL VECADOLCBC(1.LL).GAM(1.KLL).GAM(1.KL))
                                                                            C1515400
      IF (LEGU)KI = K-1
                                                                            C1515500
      IF (LEGUIFRINT 205 . KL. KI.L. KLL.LL
                                                                            C15156CC
      KLL = KL
                                                                            C1515700
      LL = K
                                                                            C1515800
      CO TC 5
                                                                            C1515900
    3 CCATINUE
                                                                            C15160C0
 EDAS CONTINUE
                                                                            C15161CO
      IF (. NOT. LEGU) GO TO 1000
                                                                            C1516200
      FRINT 23C
                                                                            C1516300
      CO 23 K=1.NBOD
                                                                            C1516400
      FRINT 225
                                                                            C15165C0
      CO 23 LEK.NBOD
                                                                            C15166C0
      KL = KIC(NUL.K-1.L)
                                                                            C15167CO
      K1 = K-1
                                                                            C15168CC
   23 PRINT 231. MI.L.KL. (GAM(I.KL).[=1.J)
                                                                            C15169C0
      FRINT 220
                                                                            C1517000
 1000 CENTINUE
                                                                            C15171C0
C
                                                                            C1517200
C
      CCMPLTE ELEMENTS OF SYSTEM INERTIA TENSOR MATRIX
                                                                            C1 51 73CC
C
                                                                            C1517400
C
      AFTER FIRST PASS RECCMPLIE CALY TIME VARYING ELEMENTS OF XCIC
                                                                           C1 51 7500
         1) IF K CONTAINED IN SXT. ELEMENTS OF ROWK FROM COLUMN 1 TO K C1517600
C
C
            AHE EITHER ZERO OR ASSUMED TIME VANYING. INTERNAL LOGIC. SUPCISITION
C
            JA SET SPICK-11. SKIPS ZER. ELEMENTS
                                                                            C1 51 78CC
C
        2) IF K CONTAINED IN SXT, ELEMENT IN NUW NBOD+1 CULUMN K IS
                                                                            C1517900
C
            ASSUMED TIME VARYING
                                                                            C1518000
C
         3) IF K NUT CONTAINED IN SXT ABOVE ELEMENTS ASSUMED CONSTANT ANCISTBLOC
            EULAL TO VALUE DEFINES ON FIRST PASS THROUGH
C
                                                                            C1518200
C
         4) IF HINGE K-1 IS A FIGIR HINGE INERTIA TENSONS IN FOR K NOT CIEIE300
C
            NEEDED FOR DYNAMICS HONEVER THEY ARE NECESSARY FOR CONSTRAINCIEISAGE
C
            TORUNES. NO LOGIC TO AVOID THIS SINCE IT WILL BE MARCLY EVERCISIBSON
      SXT STURED IN ST3 ARRAY
                                                                            C1518600
      IF (NST3.60.0) GU TC 5046
                                                                            C15187CC
      CC 6 KF=1.NST3
                                                                            C15188C0
      IF (LEGU)FRINT 230
                                                                            C1518900
      K = ST3(KP)
                                                                            C1519000
```

```
IN = KTC(NBUD.O.K-1)
                                                                             C1519100
      SET SI(IN) DEFINES BODY LABELS ON PATH FROM FINGE POINT ZERO TO
                                                                             21519200
        CENTER OF MASS OF BODY K
C
                                                                             C1519400
      (ALL UNPACISTI.NSTI.SI(IN))
                                                                             C15194C0
      IF (RELJ(K)) GU TO 7
                                                                             C1 51 95 00
C
                                                                             C1519600
      SCCY K IS A LINEAR OSCILLATOR
C
                                                                             C1519700
      IF (LEGUIFRINT 206. K
                                                                             C1519800
      IF (LEGUJFRINT 232 . K
                                                                             C1519900
      IF (LEGUIPRINT 207.K. (STI(JJ).JJ=1.NSTI)
                                                                             C15200C0
      IF (LEGUIPHINT 229
                                                                             (1520100
      FILL UP FOR K TO CIAGONAL
                                                                             C1520200
      IF (NSTI . EQ. O) GU TC 6
                                                                             C1520300
      CO 8 11=1.NST1
                                                                             C1520400
      I = STI(II)
                                                                             (1520500
      KI = KTI(NO1 .K .I)
                                                                             C1520600
      IF (1 .EU .K) GU TO S
                                                                             C15207C0
      IK = 510(NO1.1-1.K)
                                                                             C' 520800
      CALL SCLV(XMAS(K).GAM(1.IK).TEM)
                                                                             C1520900
      CALL DYCF (TEM. XDIC(11.1.KI))
                                                                             C1521000
      IF (LEGU) | 1 = 1-1
                                                                             C1521100
      IF (LEGU)FRINT 208. KI.K.I.K.IK.K.II.K
                                                                             C1521200
      GD TC 8
                                                                             C1521300
    S IF (CT4.NE.1) GC TC E
                                                                             C1521400
      AK = KTI(AUL.NBI.K)
                                                                             C1521500
      CO 1C +=1.3
                                                                             01521600
      XCIC(N. P.KI) = XMAS(K)
                                                                             (1521700
   IC ADIC(P.P.NK) = XMAS(K)
                                                                             C1521800
      IF (LEGJ)FRINT 210. KI.K.I.K
                                                                             C1521900
      IF (LEGUIFHINT 21C. NK.NBI.K.K
                                                                             C1 522000
    e CONTINUE
                                                                             C1522100
      CO TC 6
                                                                             C1522200
C
                                                                             C1522300
    7 CENTINUE
                                                                             C15224C0
      ECCY K IS A RIGIO EODY
                                                                             C1 122500
      IF (LEGU)FRINT 211 . K
                                                                             C1522600
      IF (LEQUIFRINT 232. K
                                                                             C1522700
      IF (LEGUIPHINT 229
                                                                             (1522800
      IF (LEGUIPHINT 207.K. (STI(JJ).JJ=1.NSTI)
                                                                             C1522900
      CG 11 1=1.3
                                                                             C1523000
      TEM3(1) = 0
                                                                             01523100
      CO 11 J=1.3
                                                                             C1523200
   11 TEPI (1.J) = 0
                                                                             C1523300
C
                                                                             C1523400
C
        SPI(K-I) = SET CF BODIES IN NEST K-I CUNTRIBUTING TO PSUECC INERCLE23500
C
                    TENSORS OF NEST K-1
                                                                             C1523600
      CALL UNFACISTE . NST2 . SPICE-11)
                                                                             C1523700
      IF (LEGU) FHINT 212 . K.K. (ST2(M) . M=1 . NST2)
                                                                             C152 1800
      IF (LEJUIPRINT 229
                                                                             C1523900
      IF (LEGU) FRINT 217
                                                                             C1524000
      IF (N 51 a . EQ . O) GO TC 5047
                                                                             C1524100
      CC 12 LL=1.NST2
                                                                             C1524200
      L = STELLL)
                                                                             C1 524 300
      KL = KTO(NB1.K-1.L)
                                                                             C1524400
      (ALL SCLV(XMAS(L).GAM(1.KL).TEM)
                                                                             C1 5245CC
      CALL VECADD (TEM3. TEM. TEM3)
                                                                             C1524600
      IF (LEGU)KI = K-1
                                                                            C15247C0
      IF (LEGL) FRINT 213. L.KL.L.KI.L
                                                                             C1 524800
      IF (.AUT.ROLO(L)) GO TO 12
                                                                             C1 524900
      (ALL CYADD(TEM1.XIC(1.1.L).TEM1)
                                                                             C1125000
```

```
IF (LEGUIFHINT 215. L
                                                                           C1525100
  12 CUNTINUE
                                                                           (1525200
 5347 CONTINUE
                                                                           C1525300
      AK = KTI(NEL.NEL.K)
                                                                            01525400
      CALL CYCF(TEM3.XDIC(1.1.NK))
                                                                           (1525500
      IF (LEGUJFRINT 218. NK. NBI.K
                                                                           C15256CC
      FILL CUT HOW K OVER TO DIAGENAL
C
                                                                           C1525700
      IF (NST1.E0.0) GU TO 6
                                                                           C1525800
      CD 13 11=1.NST1
                                                                           C1525900
      1 = 571(11)
                                                                           01005210
      KI = KTI(NBI .K .I)
                                                                           C1526100
      CO 14 M=1.3
                                                                           C15262CO
      CO 14 N=1.3
                                                                           C15263C0
   14 TEP2(P.A) = C
                                                                           (1520400
      IF (LEGU)FRINT 220
                                                                           C15265C0
      IF (NST2.: 0.0) GO TG 5048
                                                                           C1526600
      DO 15 LL=1.NSY2
                                                                           C1526700
      L = ST2(LL)
                                                                           C1526H00
      KL = KIC(Nd1.K-1.L)
                                                                           C15269C0
      IL = KTC(NHI . I-I . L)
                                                                           C1 52 7000
      (ALL SJELP(GAM(1.KL).GAM(1.IL).XMAS(L).TEM4)
                                                                           C1527100
      CALL CYACO(TEM2.TEM4.TEM2)
                                                                           C1527200
      IF (LEQUIKI = K-1
                                                                           C1527300
      1F (L EQU) 11 = 1-1
                                                                           C1527400
      IF (LEGU)FRINT 221. L.KI.L.II.L.II.L.KI.L.KL.IL.L
                                                                           C1527500
      IF (LEGUIFRINT 222
                                                                           C1527600
  15 CONTINUE
                                                                           C1 5277CO
SOME CONTINUE
                                                                           C15278C0
      CALL CYACULTEMI.TEM2.XCIC(1.1.XI))
                                                                           C1527900
      IF (LEJU) FRINT 224. KI.K.I
                                                                           C1528CCC
  13 CENTINUE
                                                                           C15281C0
    & CONTINUE
                                                                           01528200
SCAF CONTINUE
                                                                           C1528300
      1F (C14.NE.1) GC TC 17
                                                                           C1526400
      AN = KTI(NOL.NEL.NEL)
                                                                           C15285C0
      CO 16 M=1.NOCD
                                                                           C1528600.
      CO 16 1=1.3
                                                                           C15287C0
   IE DIC(I.I.NN) = XDIC(I.I.NN) + XMAS(K)
                                                                           C1528800
      IF (LEUJIFHINT 226. NN. NEI . NEI
                                                                           C1*2890C
   17 CONTINUL
                                                                           C1529000
      IF ( . NLT . LEUU) GO TO ICOI
                                                                           00162513
      FRINT 230
                                                                           C1529200
      CC 24 K=1.No1
                                                                           01529300
      CO 24 1=K.NB1
                                                                           C1529400
      IK = KT1(N81.1.K)
                                                                           01529500
      FRINT 229
                                                                           C1529600
      FR INT 232. (XCIC(1.L.IN).L=1.3)
                                                                           C15257C0
      FRINT 234. I.K.IK.(XDIC(2.L.IK).L=1.3)
                                                                           C1529800
      FR INT 233. (XDIC(3.L.IK).L=1.3)
                                                                           01529900
   24 CONTINUL
                                                                           01532000
1001 CENTINUE
                                                                           C1530100
                                                                           C1530200
 202 FORMAT (' SXT = '.Z8.' ELEPENTS OF SXT = '.1015 )
                                                                           C1530300
505 FORMAL (. PAD = .'SH', EFENE ILP OL PAD = .'1012 )
                                                                           22405313
 204 FORMAT (' JAM('.12.') = GAM('.12.'.'.12.') = CAC('.12.') ')
 205 FORMAT ( GAM( '.12. ') = GAM( '.12. '.12. ') = GAM( '.12. ') + CBC( '.1(1530600
                                                                           C15307C0
 206 FCRMAT ( BCDY '.12. IS A LINER OSCILLATOR ')
                                                                           C1530800
 207 FORMAT ( ' NUN-ZERC COLUMNS OF HUM ". 12." OVER TO DIAGUNAL ARE ". 1001930400
     . 15 ./ )
                                                                           C1531000
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208 FORMAT (' XDIC(',12,') = XDIC(',12,',',12,') = XMAS(',12,')*DYOF(GC1531100
  *AM(',12,')) = XWAS(',12,')*CYUP(GAM(',12,',',12,')) ')
                                                                      C1531200
21C FORMAT (' XDIC(',12,') = XCIC(',12,',',12,') = XMAS(',12,')*1 ') C1531300
211 FORMAT ( BCDY '.12. IS A RIGID BCDY ')
                                                                       C153140C
212 FORMAT ( * TO GET INERTIA TENSORS IN ROW *.12. * COLUMNS 1 THROUGH C1531500
   *'. 12.' SLM UVER ECCIES '.1015)
                                                                       C1531600
213 FORMAT (5x, ' TEM3 = TEM3 + XMA3(', 12, ') + GAM(', 12, ') = TEM3 + XMAS(C15317CC
   *'.12.')*GAM('.12.'.'.12.') ')
215 FORMAT (5x.' TEM1 = TEM1 + XIC('.12.') ')
                                                                       C15319C0
217 FORMAT (Ex.' TEM1 = 0 . TEM3 = 0 ')
                                                                       C1532000
218 FORMAT ( * XDIC( *, 12, *) = XDIC( *, 12, *, *, 12, *) = SKEW( TEM3) *)
                                                                       C1532100
220 FORMAT (5x. TEM2 = 0 1)
                                                                       (1532200
221 FORMAT (5x, TEM4 = XMAS(',12,')*( GAM(',12,',',12,').GAM(',12,','C1532300
   *,12,')*1 - GAM(',12,',',12,')GAM(',12,',',12,') ) = SUEOP(GAM(',12C1532400
   *,').CAM(',12.').XMAS(',12.')) ')
                                                                       C153250C
222 FORMAT (5x. TEM2 = TEM2 + TEM4 1)
                                                                       C1532600
224 FORMAT (' XDIC(',12,') = XDIC(',12,',',12,') = TEM1 + TEM2 ')
226 FORMAT (' XDIC(',12,') = XDIC(',12,',',12,') = (TUTAL MASS)*1 ') (1532800
228 FORMAT ('1 SUBROLTINE XCY ENTERED ')
                                                                       C1532900
225 FORMAT ( . .)
                                                                       C15330C0
230 FORMAT (3(/))
                                                                       C15331C0
231 FORMAT (' GAM(',12,',',12,') = GAM(',12,') = ',3D17.6)
                                                                       C1533200
232 FORMAT (/. *
                      COMPLIE ELEMENTS IN RUM ",12," OF INERTIA MATRICISSES
   4x './)
                                                                       C1533400
233 FCFMAT (27x, 3D17.8)
                                                                       C1 53 3500
234 FORMAT (' XDIC(',12,',',12,') = XDIC(',12,') = ',3C17.8)
    SE TUEN
                                                                       C1533700
    ENC
                                                                       C1533800
```

```
C
                                                                             C1600000
     SUPRCUTINE ETA
                                                                             C1600100
C
       USE TO COMPUTE GYROSCOPIC CROSS COUPLING TERMS DUE TO
                                                                             C1620200
        1) INERTIA CROSS COUPLING
C
                                                                             C1600300
         2) CENTRIPITAL CROSS COUPLING
C
                                                                             C1600400
C
         3) CURIOLIS CROSS CCLFLING
                                                                             C1600500
C
                                                                             C1600600
C
     LET:
                                                                             C1620700
C
        ETC(1.K) = COMPENENTS OF GYRUSCOPIC CROSS COUPLING TORQUE
                                                                             C162280C
C
                     CN NEST K-1
                                                                             C1600900
C
                                                                             C1601000
C
                                                                             C1601100
      INFLICIT REAL+8(A-F.O-Z.1)
                                                                             C1601200
      LOGICAL FG1. FG2. FG3. FG4. F35. INERF. HOLD. LEQU. LINIT(1)
                                                                             C1601300
                      LRUNGE . LTRNSI . LVDIV . LEQUIV . LTRAN . . LTRAN . LTATE . LXDY . LETA . LTDFQU .
     LCCICAL
                                                                             C1621420
                                                                             (1 € 01500
                                        . LANGLE . LSETUP . LSIMO
                       LGFDOT . LDCT
                                                                             C1601600
C
                                                                             C1601700
C
                                                                             C1601800
C
                                                                             C1601900
C
                                                                             C1602000
C
                                                                             C1602100
C
                                                                             C1602200
      INTEGER
                                                                             C1602300
                    . CT2 . CT3 . CT4 . CT5
. SCRDUM, SCR . SFKDUM, SFK
     . ANDRK . CTI
                                                        . FCON . PCON .
                                                                            C1602400
                                                                         . 01602500
                                                       . SFR
                                                                . SG
     . SCNDUM. SCN
          . SIG
                    . SIXDUM. SIX . SKOUM . SK
                                                        . SL
                                                                 . SLK
```

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. SNA
            . SMCDUM. SMC . SMV . SUK
                                             . SPIDUM. SPI . SQF . C1602700
             . SR . SSCN . SEIX . SVA . SVb . SVD . SVI
     * SGL
                                                                    . (1602800
            . SVP
                                             TONU . SMAL . SEU . C160290C
, NMGDS . SFCC . SCC . C1603000
     * SVM
                    . SVQ . SXM . SXT
                    . NFL XB . SFLX
             . SCG
                                     . SFXM
     * SC
                    . IZINIT(1)
                                     . SD
     · IINIT(1)
                                                                        C1603100
C
                                                                        C1603200
C
                                                                        C1603300
     REAL .
                    . CNF (3.10) . ETIC (3.10) . ETMC (3.10) . C1603500
     * ANGC (23)
     • FLQ (3,20) • FLE (3,3,20), FLH (3,3,20),
                                                                        C1603600
     * THACO (33) . YMCD (3.2.11). RINIT (1) . HZINIT(1)
                                                                        C1603700
C
                                                                        (1603800
C
                                                                        C1 € C3900
      COMMEN /LDEBUG/ LRUNGE . LTRNS! . LVDIV . LEQUIV . LTRAN .
                                                                       01604000
                      LTRANV , LRATE , LXDY , LETA , LTDFQU .
                                                                       C1604100
                      LOFDOT . LOCT . LANGLE . LSETUP . LSIMO
                                                                       C1604200
C
                                                                       C1624300
C
                                                                       (1604400
     COMMEN /LUGIC/ FG1. FG2. FG3. FG4. FG5. INERF. RELO(10)
                                                                       C1604500
C
                                                                       C1604600
C
                                                                        C16047C0
     CEMMEN /INTG/ AWORK(200).
                                                                        C1634800
                    . C12
                                     • CT3
     * CTL
                                                    . CT4
                                                                       C16C4900
     * CT5
                    . FCON (33)
                                    . JCCN (10)
                                                    . LCCN (22)
                                                                    . 01605000
                    . NB1
                                                    . NCTC
     * MC
            (10)
                                     . NBCD
                                                                       01635100
     * NEER
                    . NFKC
                                     . NFRC
                                                    . NLOR
                                                                       C16052C0
                    . MMO
     * NHV
                                     . NMUA
                                                    . NSVP
                                                                       C1605300
                    . FCCN (11)
     . NEVC
                                    . 50
                                                    , SFR (33)
                                                                       C1605400
                                    · sig
     * SG
                    . 51
                            (55)
                                                    . SL
                                                                       C1605500
                                     . SCK (11)
                                                           (11)
     * SLK
            (33)
                    . SMA
                            (10)
                                                    . SOF
                                                                        C1405600
     • SCL (11)
                    . SHV
                                                    . SSCN
                                     . SR
                                                                       C1 € 25700
                    . SVA
     * SSI *
                                     . SVB
                                                    . SVC
                                                                       CLEOSHOC
                     . SVM
                                                    . SVQ (33)
     * SVI
                                     . SVP
                                            (22)
                                                                       (1605900
                                                                       (1600000
                                                    . SMAL
     * CXM
            (2.10) . EXT
                                     . TUHU (97)
                    . NTQ
     . SEU
                                     . SC
                                             (66)
                                                    . SCG
                                                                       C160610C
                    . SFLX
                                     . SFXM (10)
                                                                    . C1636200
     * NFL >d
                                                    . NMUDS
     • SFCC
                     . SCC (1C)
                                                                        C1606300
                                                                       C1606400
C
C
                                                                        C1606500
     CEMMEN /INTUZ/
                                                                       C16C660C
                    . SCN
     * SCNEUM
                                                                    . C1696700
                           (5)
                                    . SCRDUM
                                                   . SCR
                                                           (9)
                                    . SIXDUM
                                                    . SIX
                                                                    . (1696800
     . SFKCUM
                    . SFK
                            (5)
                                                            (9)
     * SKOLM
                    . SK
                            (5)
                                    . SPIDUM
                                                    · SPI
                                                             (9)
                                                                       01606900
     . SMCCUA
                    . SMC
                                                                       C1607000
                             (4)
C
                                                                       C1607100
     COMMEN THEALT
                                                                       C16C7200
                                            (10) , CCMC (3.11) , (33) , FOME
            (3.10) . CAC
(3.11) . ETC
                            (3.10) , CLM
(3.11) , ETM
     . .
                                                                       C1607300
                                                    . FUMC (3.11) .
     . DCMC
                                                                       C1607400
                                    . HM
     . GAM
           (3.06) . H
                                             (3.10) . HMC
                                                            (3.10) .
                                                                       C1607500
    * HMC* (10) , PHI (3.11) , PLM
* OFC (3.33) , GL (3.22) , QLC
                                                    . QF
                                                            (3,33) ,
                                                                       C1607600
                                             (10)
                                                            (3.11) .
                                                    . FOMC
                                             (3.22)
                                                                       C1607700
                                                    . THAD (33)
                                                                       C1607800
                                      THA
                                             (33)
                   , THAW (10)
                                    . XDIC (3.3.66), XI
                                                            (3.3.1C). C16C790C
     * THAC. (10)
     * XIC (2.3.10) . XMAS (10)
                                             (33.33) . XMT (3.3.10). C1608000
                                    . XMN
     4 TLG (33) , FLA (3,20) , FLB (3,20) , FLC (3,20) , FLD (3,3,20), FLJ (3,3,20), CAO (3,10) , XID (3,3,10), FLIRC (3,10) , FLCRC (3,10) , FLAC (3,20) , FLQC (3,20) ,
                                                                       C160810C
    * FLD
                                                                       (1408200
                                                                       C1 + C8300
    * FLC N (20) , ZETA (20) , FCF (3,3,40), FCK (3,40) , C1698400
    . TIMEND
                                                                       C1 €08500
C
                                                                       C16C86C0
```

```
C
                                                                            C16CE700
      COMMEN /FEALZ/
                                                                            C1 € 0 88C 0
                              (3.10) , CBCDUM(1.3) , CBC
     * CEDLN (1,3) , CE
                                                                (3.10)
                                                                            CIEORAOC
     * XMCCUM(1.1.5) , XMC (3.3.10), CdN(3)
                                                                            C1609000
C
                                                                            C1609100
C
                                                                            C1609200
      EQUIVALENCE (ETM(1).THACC(1))
                                              . (XMN(1.1). ANGD(1))
                                                                            C1609300
                   (XMN(1.3).YMCC(1.1.1))
                                              . (XMN(1.6), CNF(1.1))
                                                                            C1609400
                                               . (XMN(1.10).ETMC(1.1)) .
                   (XMN(1.8),ETIC(1.1))
                                                                            C1609500
                   (FLB(1.1).FLG(1.1))
                                              . (FLE(1.1.1).FLD(1.1.1)).
                                                                            (1605600
                   (FLH(1,1,1),FLJ(1,1,1))
                                                                            C1609700
     .
                   (FGI.LINIT(1))
                                              . (CA(1.1). # INIT(1))
                                                                            C1609800
                   (CHDUM(1.1).FZINIT(1))
                                              . (AWURK(1). IINIT(1))
                                                                            C1609900
                   (SCNDLW.IZINIT(1))
                                                                            C1 €1 0000
C
                                                                            C161010G
      INTEGER STILLO).ST2(10).ST3(10).ST4(10).SET(10).SFXMN
                                                                            C161 0200
      CIMENSILN TEM(3). TEM1(3). TEM2(3). TEM3(3). TEM4(3). TEM5(3). TEM6(3) C1610300
      CIMENSICN TEM7(3,3).TEM8(3,3).TEM9(3).TEM10(3).FLEC(3,3)
                                                                            C1613400
      EQLIVALENCE (LETA, LEGU)
                                                                            C1610500
C
                                                                            C1 €1 C600
      IF (LEGU)FRINT 240
                                                                            C1 €1 0700
      00 1 1=1.3
                                                                            C1610800
      TEM3(1) = 0
                                                                            C1610900
      TE+6(1) = 0
                                                                            C1611000
    1 ETC(1.NE1) = 0
                                                                            C1611100
C
                                                                            C1611200
      USE SETS SSIX AND SSCN TO REDUCE HEDUNDANCY IN CHOSS COUPLING COMPCIEITEDO
C
      COMPLIE INTERTIAL CROSS COUFLING CONTRIBUTIONS FOR EACH BODY
                                                                            C1611400
      IF (LEGU)FRINT 233
                                                                            C1611500
      CALL UNPACISTI . NSTI . SSIX)
                                                                            C1611600
      IF (NET1 . EQ . 0) GO TC 5049
                                                                            C16117C0
      CC 3C 11=1.NST1
                                                                            C1611800
      1 = 511(11)
                                                                            C1611900
      CALL VXCYUV(FGMC(1.1).XIC(1.1.1).ETIC(1.1))
                                                                            C1612000
      IF (LEQU)FRINT 239. 1.1.1.(ETIC(J.1).J=1.3)
                                                                            C1612100
   3C CONTINUE
                                                                            C1612200
 5345 CONTINUE
                                                                            C1612300
C
                                                                            C1612400
C
                                                                            C1612500
      COMPLTE FUNCE ASSOCIATED WITH CENTRIPITAL ACCELERATION OF EACH
C
                                                                            C1612600
C
      BCDY IN THE SET ESCN
                                                                            C1612700
      (ALL UNPAC(ST2.NST2.SSCN)
                                                                            C1612800
      IF (LEGU) FRINT 234
                                                                            C1612900
      IF (NST2.EQ.0) GO TC 5050
                                                                            C1 € 1 3000
      CO 31 III=1.NST2
                                                                            C1613100
      II=NST2-(III-1)
                                                                            C1613200
      1 = 572(11)
                                                                            C1613300
      IF (1 .EQ . 1) GO TO 31
                                                                            C1 €1 3400
      (ALL THIPVP(FOMC(1.JCON(1)).CBC(1.1).CNF(1.1))
                                                                            C1613500
      IF (JCCN(1).EG.1) GC TO 32
                                                                            C1 € 1 3 6 0 0
      CALL VECADD(CNF(1.JCON(1)).CNF(1.1).CNF(1.1))
                                                                            C1613700
      IF (LEQU)PRINT 235. I.JCON(I).JCON(I).JCON(I).I
                                                                            01613800
      CO TC 31
                                                                            C1613900
   32 CONTINUE
                                                                            C1614000
      IF (LEGU)PRINT 236. I.JCON(I).JCON(I).I
                                                                            C1614100
   31 CONTINUE
                                                                            C1614200
SOEC CONTINUE
                                                                            C161430C
      IF (LEGU)PRINT 229
                                                                            C16144C0
      IF (NET2.EQ.0) GO TC 5051
                                                                            C1614500
      CO 33 111=1.NST2
                                                                            C1 € 1 4 6 0 0
```

```
11=NST2-(111-1)
                                                                             C1614700
       1 = 572(11)
                                                                             C1614800
       IF (1.EJ.1) GC TO 33
                                                                             01614930
      CALL TRIPVP(FOMC(1.1).CAC(1.1).TEM)
                                                                             (1615000
       IF (LEGL)FRINT 237. 1.1.1.1.1.1
                                                                             C1615100
   35 (ALL VECADD(CNF(1.1).TEM.CNF(1.1))
                                                                             C1615200
      (ALL SCLV(XMAS(I).CNF(1.I).CNF(1.I))
                                                                             C1615300
   33 CONTINUE
                                                                             C1615400
 5051 CONTINUE
                                                                             C1615500
       IF (.NCT. LEGU) GU TO 1000
                                                                             (1615600
      FRINT 225
                                                                             C1 61 5700
      IF (NST2.E3.0) GO TC 1000
                                                                             (1615800
      CC 36 11=1.NST2
                                                                             C161590C
      1 = 512(11)
                                                                             C1616000
       If (I .Eu . 1) GO TO 36
                                                                             C1616100
      FRINT 23E. 1.(CNF(J.1).J=1.3)
                                                                             C1616200
   JE CONTINUE
                                                                             C1616300
 1000 CONTINUE
                                                                             C1616400
                                                                             C1e16500
C
                                                                             C161660C
C
                                                                             C1616700
C
      DEFORMATION CONTRIBUTIONS TO CHUSS COUPLING
                                                                             C16168CC
      IF (NFL XE . E J . C) GO TO 38
                                                                             01616900
      MN = 3
                                                                             C1617000
      (ALL LNPAC(SET.NSET.SFLX)
                                                                             C1617100
      IF (LEJU) PHINT 252. (SET(I).I=I.NSET)
                                                                             C1617200
                                                                             C1 €1 7300
      DO 40 NN=1 . NSET
      N = SET(NSET+1-NN)
                                                                             C1617400
      IF (LEJU) PRINT 253. N
                                                                             C1617500
      CO 37 1=1.3
                                                                             C1617600
      1EN9(1) = 3.
                                                                             C16177CC
                                                                             C1617800
      CO 37 J=1.3
   37 TEMB(1.J) = C.
                                                                             C1617900
      IF (LEGU) PRINT 231
                                                                             C1 € 18000
      SFXMN = SFXM(N)
                                                                             C1618100
      CO 35 N=1.SF XMN
                                                                             C16182C0
      MN = MN + 1
                                                                             C1618300
      (ALL SYDF(FLOC(1.MN).TEM7)
                                                                            C1618400
      CALL TENTRN(FLE(1.1.MN).XMC(1.1.N).FLEC)
                                                                             C1 €1 8500
      CALL DYADD(FLEC. TEN7. TEM7)
                                                                             20361312
      CALL SCLO(THAD(NFER+MN), TEM7. TEM7)
                                                                            C1618700
      CALL DYACD(TEMB.TEM7.TEME)
                                                                             C1618800
      CALL SCLV(THAD(NFER+MN).FLAC(1,MN).TEMID)
                                                                            C1618900
      CALL VECAUDITEMS, TEMIO. TEMS)
                                                                             01619000
      IF (. NOT . LEQU) GU TC 50C1
                                                                            C16191CC
      FRINT ZEL. MN.N.MN.N
                                                                            C1619200
      NEGX = NEER+MN
                                                                            C1619300
      FRINT 2:2. NEGX.MN.MN
                                                                            C1619400
      FRINT 243. NEUX.MN
                                                                            C1619500
 SOCI CONTINUE
                                                                            01619600
                                                                            C1 #19700
   39 CONTINUE
      CALL CYLCTV(TEMB.FCMC(1.N).FLIRC(1.N))
                                                                            C16198C0
      CALL SCLV(2.000.TEM9 .TEM9 )
                                                                            C1619900
      CALL SCLV(XMAS(N).TEM9 .TEMS.)
                                                                            C1 620000
      (ALL VECTOS (FCMC(1.N).TEMS .FLCRC(1.N))
                                                                            C1620100
      CALL VECADD(ETIC(1.N).FLIRC(1.N).ETIC(1.N))
                                                                            C1620200
      .ALL VECADD(CNF(1.N).FLCFC(1.N).CNF(1.N))
                                                                            C1620300
      IF ( . NOT . LEQU) GC TC 5000
                                                                            C1620400
                                                                            C1620500
      FRINT 244. N.N. (FLIRC(1.N) . I=1.3)
      FRINT 246. N.N.N. (ETIC(I.N).I=1.3)
                                                                            C1622600
```

```
PRINT 245, N.N.N. (FLCRC(I.N). I=1.3)
                                                                            C1620700
      PRINT 247. N.N.N. (CNF(1.N), 1=1.3)
                                                                            C1623800
                                                                            (1620900
 SOOC CONTINUE
                                                                            C1621000
   4C CONTINUE
                                                                            C1621100
   3E CONTINUE
                                                                            C1621200
                                                                            C1621300
C
                                                                            C1621400
      ELIMINATE REDUNDANT COMPLIATION IN MCMENTUM WHEEL CROSS
                                                                            C1621500
C
C
       CCUFLING CUMPUTATION EY ETHC
                                                                            C1621600
                                                                            C1621700
C
      IF (NAC.EG.O) GG TC 5CE2
                                                                            01621800
                                                                            C1621900
      IF (LEGU) FRINT 208
                                                                            C1622000
      CO 1 C M=1.NMO
      (ALL VECTOS (FCMC(1.MO(N)).FMC(1.M).ETMC(1.M))
                                                                            C1622100
      (ALL SCLV(HMGM(M).ETMC(1.M).ETMC(1.M))
                                                                           C1622200
      IF (LEGU) FRINT 207. M.M.MC(N).M.(ETMC(I.M).I=1.3)
                                                                            C1622300
   1C CENTINUE
                                                                           C1622400
 SOSE CONTINUE
                                                                            C162250C
r
                                                                            C1622600
      CC 2 K=1.NBOD
                                                                            C1 622700
      CO 3 I=1.3
                                                                            C1622800
    3 ETC(1.K) = 0
                                                                            C1622900
      K1 = K-1
                                                                            C1623000
      IF (LEQU)PRINT 225 . K1
                                                                            C1623100
      SET LF SUMMATION SETS FOR NEST K-1
                                                                            C1623200
        INENTIA CROSS CCUPLING
                                                                            C1623300
C
      (ALL UNPAC(STI.NSTI.SIX(KI))
                                                                            C1623400
                                                                           C162350C
      IF(LEQU)FRINT 200, K1.SI>(K1).(ST1(I).I=1.NST1)
        CENTRIPITAL CHESS COUPLING
                                                                           C1623600
      (ALL UNPAC(ST2.NST2.SCN(K1))
                                                                           C1623700
      IF(LEGU)FRINT 201, K1, SCN(K1), (ST2(1), I=1, NST2)
                                                                           C162380C
         CCRICLIS CRCSS COUPLING
C
                                                                           C162390C
      (ALL UNPAC(ST3.NST3.SCF(K1))
                                                                           C1624000
      IF (LEGU) FRINT 202 . K1 . SCh(K1) . (ST3(1) . I=1 . NST3)
                                                                           C1624100
C
        MCMENTUM WI LEL CROSS CCUFLING
                                                                           C1624200
      CALL UNPAC(ST4.NST4.SMC(KI))
                                                                            C1624300
      IF(.NCT. LEGU) GO TO 1COL
                                                                           C1624400
      FRINT 205. KI, SMC (KI) . ($74(I) . I=1.NST4)
                                                                           C1624500
                                                                           C1624600
C
                                                                            (1624700
     FRINT 225
                                                                           C162480C
      FRINT 203. K
                                                                           C16249C0
      IF (K.NE. 1) GO TO 5
                                                                           C1625000
      PRINT 203. NBI
                                                                           C162510C
      FRINT 23C
                                                                           C162520C
    5 CONTINUE
                                                                           C1625300
                  INERTIA CRESS COUPLING
C
                                                                           C1625400
      FRINT 241
                                                                           C1625500
      FRINT 226
                                                                           C1625600
 1001 CONTINUE
                                                                           C1625700
      IF (. NJT. RULU(K)) GC TO 4
                                                                           C1625800
      IF (LEQUIPHINT 204 . K.K
                                                                           C1 625900
        SUP CVER UNLY THOSE ECCIES OF NEST K-1 WHICH SIGNIFICANTLY
C
                                                                           C162620C
         CONTRIBUTE TO INERTIAL CROSS COUPLING IN EQUATIONS OF
C
                                                                           01626100
C
          POTICN OF NEST K-1
                                                                           C1626200
      IF (NST1.EQ.O) GO TC 4
                                                                           C1426300
      CO 6 LL=1.NST1
                                                                           C1626400
      L = STI(LL)
                                                                           C1626500
      IF (LEGUJFRINT 205. K.K.L
                                                                           (1626600
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e (ALL VECSUBLETC(1.K).ETIC(1.L).ETC(1.K))
                                                                           C1626700
      NOTE RECUNDANT VECTUR ADDITIONS LESS CUSTLY THAN LUGIC NEEDED TO C16268CO
C
       AVUID THEM
C
                                                                           C1626900
    4 CONTINUE
      IF(LEGU)FRINT 216. K.(ETC(I.K). I=1.3)
                                                                           C1627100
C
                                                                           C162720C
C
                       CENTRIPITAL CHUSS COUPLING
                                                                           C1627300
      IF (LEGU) FRINT 241
                                                                           C1627400
      IF (LEGU)FRINT 227
                                                                           C1627500
      IF (NST2.EJ.O) GU TC 7
                                                                           C1627600
      CO 8 1=1.3
                                                                           C1627700
      TEM4(1) = 0
                                                                           C16278C0
    E TEM2(1) = 0
                                                                           C1 627900
        SUM JVER ONLY THOSE ECCIES JF NEST K-1 WHICH SIGNIFICANTLY
                                                                          C1628000
C
          CENTRIBUTE TO CENTRIFITAL CROSS COUPLING IN EQUATIONS OF
C
                                                                           C1628100
C
          ACTION OF NEST K-1
                                                                           C1628200
      IF (LEGUIPRINT 206
                                                                           C1628300
      IF (NET2.EQ.0) GO TC 5053
                                                                           C1628400
      CO 9 LL=1.NST2
                                                                           C1628500
      L = ST2(LL)
                                                                           C1628600
      LC = L
                                                                           C1628700
      IF (LC.EG.1) GC TO S
                                                                           C1628800
      IF (RELU(K)) GO TU 22
                                                                           C1 628900
      (ALL VECSUB(TEM4.CNF(1.L).TEM4)
                                                                           C162900C
      IF (LEQUIFRINT 211. L
                                                                           C1629100
      GO TC 9
                                                                           C162920C
   22 IF (K .NE . 1) GO TO 14
                                                                           C1626300
      CALL VECSUB( TEM3. CNF(1.L). TEM3)
                                                                           C1625400
      IF (LEGU) PRINT 212. L
                                                                          C1 €2 9500
   14 KL = KTC(NB1.K-1.L)
                                                                           C1629600
      (ALL VECTOS (GAM(1.KL).CNF(1.L).TEM)
                                                                          C1629700
      (ALL VECSUB( TEM4 . TEM . TEM4)
                                                                           C1629800
                                                                          C1629900
      IF (LEQU)KI = K-1
      IF (LEGU) FRINT 213. KI.L.L
                                                                          C1 € 30000
                                                                          C1630100
      IF (LEGU)FRINT 229
    S CONTINUE
                                                                           C1630200
 5052 CONTINUE
                                                                          C1 # 30300
      (ALL VECADD(ETC(1.K).TEM4.ETC(1.K))
                                                                          C1 ( 3040C
      IF (LEGU)PRINT 214. K. K. (ETC(I.K).I=1.J)
                                                                          C1630500
      IF (K.NE.1) GC TO 7
                                                                          C1630600
      CALL VECADU(ETC(1.NB1).TEM3.ETC(1.NB1))
                                                                          C1630700
      IF (LEGU) PRINT 215. NAT. NET. (£TC(1.NB1).1=1.3)
                                                                          C1 # 30800
                                                                          C1630900
    7 CONTINUE
                                                                          C1631000
C
                       CCRIOLIS CROSS COUPLING
                                                                          C163110C
      IF (NST3.EQ.O) GU TC 15
                                                                          01631200
      IF (LEGU) FRINT 241
                                                                          C1631300
      IF (LEGUIFRINT 228
                                                                          C1631400
                                                                          C1631500
      CO 16 1=1.3
                                                                          C1631600
   16 TENS(1) = 0
C
       SUN OVER UNLY THOSE BUDIES OF NEST K-1 WHICH SIGNIFICANTLY
                                                                          C163170C
                                                                        C1631800
          CENTRIBUTE TO CORTOLIS CRUSS COUPLING IN EQUATIONS OF
C
          MCTICN OF NEST K-1
                                                                          C1631900
                                 IF (LEGU)PHINT 217
                                                                         C1632C0C
      IF (NSTJ.E0.0) GO TO 5054
                                                                          C1 (32200
      CO 17 LL=1.NST3
      L = ST3(LL)
                                                                          C163230C
      (ALL VECROS (FCMC(1.L). +CMC(1.L).TEM)
                                                                          C163240C
     CO 18 I=1.3
                                                                          C1632500
   18 TEM2(1) = 2.DO*XMAS(L)*TEM(1)
                                                                          C1632600
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IF (LEGU)PHINT 219. L.L.L
                                                                             C1632700
      IF (RELJ(K)) GO TO 20
                                                                             01632800
      CO 21 1=1.3
                                                                             C163290C
   21 TEM5(1) = -TEM2(1)
                                                                             C1633000
      IF (LEGU) FRINT 221
                                                                             C1633100
      GO TC 17
                                                                            C1633200
                                                                             C1633300
   2C KL = KTC(NBI-K-I-L)
      CALL VECTUS (GAM( 1.KL) . TEM2 . TEM)
                                                                             C1633400
      (ALL VECSUBLIEMS . TEM . TEME)
                                                                            C1633500
      IF (LEGU)KI = K- 1
                                                                            C1633600
      IF (LEGU)PRINT 222 . KI.L
                                                                             C1633700
      IF (K . NE . 1) GO TO 15
                                                                             C1633800
      (ALL VECSUBLIENG. TEM2. TEM6)
                                                                             C1633900
      IF (LEQU) FRINT 220
                                                                            C1634000
   19 CONTINUE
                                                                             C1634100
      IF (LEGU)PRINT 229
                                                                            C1634200
   17 CONTINUE
                                                                             C1634300
 5054 CONTINUE
                                                                            C1634400
      CALL VECAUDIETC(1.K).TEME.ETC(1.K))
                                                                            C1634500
      IF (LEGU) FRINT 223. K.K. (ETC(1.K), 1=1.3)
                                                                            C163460C
      IF (K . NE . 1) GO TO 15
                                                                            C1634700
      (ALL VECADD(ETC(1.NB1).TEM6.ETC(1.NB1))
                                                                            01434800
      IF (LEGU) FRINT 224. NOI. NEI. (ETC(I.NOI). 1=1.3)
                                                                            C1634900
                                                                          C1635000
   15 CONTINUE
C
                                                                          C1635100
C
                                                                            (1635200
                     MOMENTUM BEEL CROSS COUPLING
C
                                                                            C1635300
      IF (NST4.EQ.C) GO TC 5055
                                                                            C1635400
      IF (LEQUIFRINT 241
                                                                            C1635500
      IF (LEGLIFRINT 210
                                                                            C1635600
C
                                                                            C1635700
      CO 11 MM=1.NST4
                                                                            C1635800
      N = 514(NM)
                                                                            C1635900
      IF (LEGU)FRINT 218. K.K.M
                                                                            C1636C00
      (ALL VECSUD(ETC(1.K), ETMC(1.M), ETC(1.K))
                                                                            C1636100
   11 CCNTINUE
                                                                            C1636200
 SOSE CONTINUE
                                                                            C1636300
      IF (LEGU) FRINT 216. K. (ETC(1.K). 1=1.3)
                                                                            C1636400
C
                                                                            C1636500
                                                                            C1636600
C
C
                                                                            C1636700
    2 CONTINUE
                                                                            C163680C
                                                                            01636900
  200 FORMAT (5x.' SIX(',12.') = ',28.' CONTRIBUTERS TO INERTIAL CROSS C1637000
     *COLPLING ARE BUDIES '.1015)
                                                                            C1637100
  201 FORMAT (EX.' SCN(',12.') = ',20,' CONTRIBUTERS TO CENTRIPITAL CROC1637200
    *SS CCUPLING ARE BCDIES '.1015)
                                                                            C1637300
  202 FORMAT (EX. * SCR(*,12,*) = *,20,* CONTRIBUTERS TO CORTULIS CHOSS (1637400
    *COLPLING ARE BODIES '.1015)
                                                                            C1637500
  203 FORMAT (' CHOSS COUPLING TORQUE ETC('.12.') = 0 ')
                                                                            C1637600
  204 FORMAT (' ETC('.12.') = ETC('.12.') ')
205 FORMAT (' ETC('.12.') = ETC('.12.') - ETIC('.12.') ')
                                                                            C1637700
                                                                            C163780C
  206 FORMAT (20x. TEN2 =0. TEN4 = 0 1)
                                                                            C1637900
  207 FORMAT (Ex. 'ETMC(',12.') = FMCM(',12.') * (FCMC(',12.') x HMC(',1261638000
     ...)) = '.3D17.8)
                                                                            C163810C
  208 FURMAT (//.5x. I INERTIAL CROSS COUPLING TERM FOR EACH MCMENTUM BEEC1638200
    *EL ' ./)
                                                                            C1638300
  205 FORMAT (EX. * SMC(',12.') = ',2d,' CONTRIBUTERS TO MOMENTUM WHEEL (1638400
     *CRESS CCUPLING ARE WHEELS' .1015)
                                                                            (1638500
                    MUMENTUM BREEL CRUSS COUPLING EFFECTS 1)
  210 FORMAT ('
                                                                            C1638600
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211 FURMAT (20x. ' TEM4 = TEM4 - CNF(", 12.") ")
212 FORMAT (20X, ' TEM3 = TEM3 - CNF('.12,') ')
                                                                         C1 € 38800
213 FORMAT (20X, ' TEM4 = TEM4 - JAM('.12,'.'.12,') x CNF('.12,') ') C163840C
214 FORMAT (' ETC('.12.') = ETC('.12.') + TEM4 = '.3D17.8)
215 FORMAT (' ETC('.12.') = ETC('.12.') + TEM3 = '.3D17.8)
                                                                         C1639000
216 FORMAT (' ETC('.12.') = '.3017.8)
                                                                         C1639200
217 FORMAT (43x. TEM5 = C
218 FORMAT (' ETC('.12.') = ETC('.12.') - ETMC('.12.') ')
                                                                         C1639400
219 FORMAT (40X, ' TEN2 = 2*XMAS(',12,') * FOMC(',12,') X KCMC(',12,'(1639500
   .) 1)
22C FORMAT (40X. TEN6 = TEN6 - TEM2 1)
221 FORMAT (40X.' TEMS = -TEM2 ')
222 FORMAT (40X.' TEMS = TEMS - GAM('.12.','.12.') & TEM2 ')
                                                                         C1 € 39800
                                                                         C1639900
223 FORMAT (' ETC('.12.') = ETC('.12.') + TEM5 = '.3017.8)
                                                                          C1643C00
224 FORMAT (' ETC(',12,') = ETC(',12,') + TEMO = ',3017.8)
                                                                         (1640100
225 FOFMAT(7(/).
                  BODY LABELS OF THOSE BODIES WHICH SIGNIFICANTLY CONT (1640300
   *RIELTE TO GYROSCOPIC CROSS COUPLING TURQUES ON NEST 1.12./)
226 FCFMAT ( '
                     INERTIA CRESS COUPLING EFFECTS ")
                                                                         C1640500
227 FORMAT ( 20x. .
                        CENTRIFITAL CROSS COUPLING EFFECTS ')
228 FORMAT ( 40x.
                         CEFICLIS CRUSS COUPLING EFFECTS ')
                                                                         C1640700
225 FORMAT ( '
                . .
                                                                          CIEACHOC
230 FORMAT (' TEMS = 0. TEM6 = 0 ')
                                                                         C1 640900
231 FORMAT (10x.' TEN8 = 0'.45x.'TEN9 = 0 './)
232 FORMAT (10x. ' TEMB = TEMB + THAD(',12,')*(FLEC(',12,') + SKEB(FLQC1641100
   ·((',12,')) ')
233 FORMAT (//.bx. I NERTIAL CHOSS COUPLING CONTRIBUTIONS OF EUCLES INC1641300
   * SET SEIX "./)
                                                                          C1641400
234 FORMAT (//.5x.º INERTIAL FORCE ASSUCIATED WITH CENTRIPITAL ACCELERCIC41500
   *ATION OF CENTER OF MASS (F EACH BODY IN SSON 1./)
                                                                         C1641600
235 FORMAT (Ex. 'CNF(',12.') = CNF(',12.') + FLMC(',12.') x (FCMC(',12.C1c41700
   *') x cuc('.12,')) ')
                                                                         CICALBOO
236 FORMAT (EX. 'CNF('. 12.') = '.10 K.
                                            'FCMC(',12,') x (FCMC(',12,C1641900
   **) x CdC(',12,')) ')
                                                                          C1642000
237 FURMAT (Ex. 'CNF(', 12.') = XMAS(', 12.') * (CNF(', 12.') + FCMC(', 12.C1642100
   *') X (FCMC('.12.') X CAC(',12.')) ')
                                                                         C1642230
23E FORMAT (EX. 'CNF('.12.') = '.3017.3)
235 FORMAT (EX. 'ETIC( '.12.') = FGMC( '.12.') x (xIC( '.12.') . FOMC( '.12(1642400
   * .* )) = ' .JD17.8)
24C FORMAT ('1 SUBROLTINE ETA ENTERED '.2(/))
                                                                         C1642600
241 FORMAT (3(/))
                                                                         C1642700
243 FCRMAT (65x, 'TEM9 = TEM9 + THAD(', 12, ') *FLAC(', 12, ')')
                                                                         C1642800
244 FORMAT (/. FLIRC('.12.') = TEMB.FOMC('.12.') ='.6x.3012.5)
                                                                         C1642900
246 FORMAT (' ETIC(',12,') = ETIC(',12,') + FLIRL(',12,') =',3012.5) C1643700
245 FORMAT (/.55x, 'FLCRC('.12,') = 2*xMAS('.12,')*FUMC('.12.') x TFP9 (1643100
   *= 1.3012.51
247 FORMAT (53x. * CNF(*,12.*) = CNF(*,12.*) + FLCRC(*,12.*) = *,9x.30101643300
   *2.5)
                                                                         C1643400
251 FORMAT (10x.' FLEC(',12,') = XMC(',12,')*FLE(',12,')*XMC(',12,')*C1643500
   **T *)
252 FORMAT (//.5x. * ELASTIC CROSS COUPLING CONTHIBUTIONS DUE TO FLEXIBC1643700
   *ILITY JF 800 IES'. 1015.//)
                                                                         C164 3HCC
253 FORMAT (///.35x. ELASTIC DEFURMATION EFFECTS DUE TO BODY . 15./) C1643900
                                                                         C1644900
    FE TUEN
                                                                         £1644100
    ENC
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C1700000
C
      SUERCUTINE TORQUE (Y.YD.NEC)
                                                                       C1730100
C
                                                                       C1700200
C
                                                                       C1700300
      IMPLICIT HEAL+8(A-+.0-2.1)
                                                                       C1700400
      LOGICAL FG1. FG2. FG3. FG4. F35. INERF. HOLD. LEQU. LINIT(1)
                                                                       C1700500
                     LRUNGE . LTRNSI . LVDIV . LEUUIV . LTRAN :
LTRANV . LRATE . LXDY . LETA . LTDRGU .
      LCGICAL
                                                                       C1700600
                                                                       C17C0700
                     LGFDOT . LDCT . LANGLE . LSETUP . LSIMO
                                                                       C1700800
C
                                                                       (1700900
                                                                       C1701000
      INTEGER
                                                                       C1701100
     . ANGEK . CTI
                   . CT2 , CT3 , CT4 , CT5 , FCUN , PCON , C1701200
                   . SCHOUM. SCR . SFKOUM. SFK . SFR . SG .
                                                                      C1701300
     . SCNCUM. SCN
           . 516
                                                           . SLK
     . 51
                    . SIXDUM. SIX
                                    . SKDUM . SK
                                                                       C1701400
                                                    . SL
                                                           . SQF
     . SPA
             . SMCDUP, SMC . SMV
                                    . SOK . SPIDUM. SPI
                                                                       C17015CC
                   . SSCh . SSIX . SVA
     4 SCL
             SH
                                            . SVB . SVC . SVI
                                                                       C1701600
                                    SXT . TOHO . SMAL . SEU
            . SVP
                                    · SXT
                                                                      C1701700
     . SVM
                    . SVQ . SXP
                   . NFLAB . SFLX
     . 50
             . SCG
                                                                       1701800
                    . IZINIT(1)
                                    . SD
     · IINIT(1)
                                                                       C1701900
C
                                                                       C1702CC0
                                                                       C170210C
     FEAL #8
                                                                       C1702200

    ANGC (33) , CNF (3.10) , ETIC (3.10) , ETML (3.10) , (1702300

     • FLO (3.20) . FLE (3.3.27). FLH (3.3.20).
                                                                       C1722400
                   . YMCD (3.2.11). HINIT (1) . HZINIT(1)
     * THACD (33)
                                                                       C1702500
C
                                                                       C1702600
C
                                                                       C17C270C
     COMMEN /LDEBUG/ LRUNGE , LTRNSI , LVDIV , LEGUIV , LTRAN , LTRANV , LRATE , LXDY , LETA , LTORQU ,
                                                                       (1702800
                                                                       C1702900
                     LOFDOT . LDCT . LANGLE . LSETUP . LSIMO
                                                                       C1703000
                                                                       C1703100
C
                                                                       C1703200
      COMMEN /LOGIC/ FG1. FG2, FG3. FG4. FG5. INERF. HBLO(10)
                                                                       C1703300
C
                                                                       C1703400
                                                                       C1703500
     COMMEN /INTG/
                      ANDRK (200)
                                                                       C1703600
                    . C12
                                    . CT3
                                                    . CT4
     * CT1
                                                                      C1703700
                    . FCON (33)
                                    . JCCN (10)
     • C15
                                                   . LCON (22)
                                                                    · C1703800
            (10)
                                    . NH 70
     . ..
                   . NEI
                                                    . NCTC
                                                                       C1703900
                    . AF .. C
     * NFER
                                    · NI F .
                                                    . NLGR
                                                                       C1704000
                    . MMO
                                    . NACA
     * NHV
                                                    . NSVP
                                                                       C17C4100
                    . PCON (11)
                                    . 50
                                                    . SFR
     . NEVC
                                                            (33)
                                                                       C1704200
                    . 51
     . 56
                            (55)
                                   . SIG
                                                   · SL
                                                                      C1704300
                                    . SUK (11)
                                                    . SUF
     . SLK
            (23)
                    . SMA
                            (10)
                                                            (11)
                                                                       C1704400
                    . SMV
     . SCL
            (11)
                                    . SR
                                                    . SSCN
                                                                       C1 704500
                                    . SVB
                                                    . SVD
     . SSIX
                    . SVA
                                                                       C1704600
                                    . SVP
                                                    . svo
     · SVI
                    . SVM
                                            (22)
                                                            (33)
                                                                      C1704700
     . SXM
            (3.10) . SAT
                                    . TORG (97)
                                                   . SMAL
                                                                       C1704800
     . SEU
                    . ATO
                                                    . SCG
                                    . sc
                                            (34)
                                                                       C1704900
     · NFL NO
                    . SFLX
                                    . SFXM (10)
                                                    . AMODS
                                                                       (1705000
     * SFCC
                    . SCC (10)
                                                                       C1705100
C
                                                                     . C1705200
                                                                       C1705300
C
      CCMMCN /INTGZ/
                                                                       C1705400
                                    . SCRJUM
     . SCNEUM
               . SCN
                            (5)
                                                   . SCR
                                                                   · C1705500
                                                            (9)
                   . SFK
                                                   . SIX
                                                                      C17C5600
     * SFKCLM
                            (5)
                                    . SIXCUM
                                                            (9)
                   . SK
     * SKOL#
                            (5)
                                    . SPIDUM
                                                   · SPI
                                                            (9)
                                                                      C1705700
     . SHCCLM
                            (6)
                                                                       C1705800
C
                                                                       C17C5900
```

```
C
                                                                            C1706000
      COMMEN /REAL/
                                                                            C1706100
                             (3.10) . CLM
              (3.10) . CAC
                                                      . CCMC (3.11) .
                                                                           C1706200
     . CA
                                               (10)
                                                        . FUMC (3.11)
                      . ETC
                                      . ETM
     . DCMC
              (2.11)
                              (3.11)
                                               (13)
                                                                            C17C6300
                                       . HM
                                               (3.10) . HMC
                                                                (3.10) .
     . GAM
                                                                           C1706400
              (3.60) · +
                      . P+1
                                                       . GF
                                                                (3,33) .
     . ---
             (10)
                              (3.11) . PLM
                                               (10)
                                                                           C170650C
                                                       . RCMC
     * QFC
              (3.33) . GL
                              (3.22) . OLC
                                                                (3.11) .
                                                                            C17C65CC
                                               (3.22)
                                                       . THAD
                                         THA
                                                                (32)
                                                                            C17067C0
                                               (35)
                                                                        .
                     . THAM (10)
                                                                (3.3.10).
                                                                           C1706800
     * THAC# (10)
                                       . XDIC (3.3.66). XI
                             (10) . XMN
(3.20) . FLB
     * XIC (3.3.10). XMAS (10)
                                               (33.33) . XMT
                                                                (3.3.10).
                                                                           C1706900
                    . FLA
                                                                (3.20) .
     . TUG
              (23)
                                              (3.20) . FLC
                                                                           C1707000
     * FLD (3.3,20), FLJ (3.3,20), CAO (3.10) . XIU (3.5,10),

* FLIRC (3.10) . FLCHC (3.10) . FLAC (3.20) . FLUC (3.20) .

* FLCh (20) . ZETA (20) . FCF (3.3,40), FCK (3.40) .
                                                                (3.3.10) .
                                                                           (1707100
                                                                            C1707200
                                                                (3.40) .
                                                                            C1707300
     . TIMEND
                                                                            C17C7400
C
                                                                            C1707500
C
                                                                            C1707600
      CCHMCN /FEALZ/
                                                                            C17C7700
     * CEDLM (1.3) . CE
                             (3.10) , CaCDUM(1.3) , CBC
                                                                (3.10) . C17C7HOO
     . XACCLM(1.1.9) . XMC
                             (3.3.10), CBN(3)
                                                                            C1707900
C
                                                                            C1708000
                                                                            C1708100
C
      CCMMCN /SATELL/
                                                                            C17C8200
     . DLMFY(1000)
                                                                            C17C8300
C
                                                                            C1708400
                                                                            C1708500
C
      EQUIVALENCE (ETM(1).THACE(1))
                                              . (XMN(1.1) . ANGE (1))
                                                                           C1708600
                   (XMN(1.3).YMCC(1.1.1))
                                               .(XMN(1.6).CNF(1.1))
                                                                           C1708700
                   (XMN(1.8).ETIC(1.1))
                                              . (XMN(1.10).ETMC(1.1))
                                                                           C17C8800
     .
                   (FLB(1.1).FLG(1.1))
                                              . (FLE (1.1.1).FLD(1.1.1)).
                                                                            C1708900
                   (FLH(1.1.1).FLJ(1.1.1))
                                                                            C1709000
                                                                            C1709100
     .
                   (FJI.LINIT(1))
                                              .(CA(1.1).HINIT(1))
                                              .(A.URK(1).[INIT(1))
                   (CHDUM(1.1).FZ[NIT(1))
                                                                            C1709200
                   (SCNDUM. IZINIT(1))
                                                                            C1709300
C
                                                                            C17C4400
      EGLIVALENCE (L'TORGU.LEGL)
                                                                            C1709500
                                                                            C1709600
C
      CIMENSIEN Y(NEG) . YC(NEG)
                                                                            C1709700
C
                                                                            C172980C
C
                                                                            C172990C
C
                                                                            C1710000
C
                                                                            C1710100
                     SYMECL LISTING OF PARAMETERS USED FROM COMMON
C
                                                                            C1710200
C
                                                                            C1710300
C
          NEUD = TOTAL NUMBER OF RIGID EUCLES AND POINT MASSES
                                                                            C1710400
C
           Nd1 = NBUD + 1
                                                                            C1710500
C
             W = GIMBAL AXIS LAREL
                                                                            C171C600
            K-1 = HINGE FCINT AT BEICH GIMBAL AXIS M IS LOCATED
C
                                                                            C1710700
       JCCN(K) = LABEL CF PODY INBOARD OF HINGE PLINT K-1
C
                                                                            C1710800
C
             K = LABEL CF BUCY CLIBUAND OF HINGE POINT K-1
                                                                            C1710900
                                                                            C1711COC
       RELC(K) = TRUE IF BODY K IS A RIGID BUDY, FALSE CTHERDISF
C
       XMAS(K) = MASS OF BODY R. (M)
C
                                                                            C1711100
   XIC(I.J.K) = INERTIA TENSOR OF BUDY K ABOUT ITS CENTER OF MASS
                                                                            C1711200
C
                 RELATIVE TO FRAME OF COMPUTATION, (MOLOOZ)
C
                                                                            01711300
     CFC(1.M) = CEMPENENTS HELATIVE TO CEMPUTING FRAME OF UNIT
                                                                            C1711400
C
C
                  VECTUR ALJNG GINBAL AXIS 4
                                                                           C1 71 1500
C
        THE (N) = DISPLACEMENT ABOUT OR ALONG GIMBAL AXIS M (R UR L)
                                                                           C1711600
C
       THAC(M) = RATE AECUT OR ALONG GIMEAL AXIS M (R/T OR L/T)
    PHI(1.NH1) = RESULTANT EXTERNAL FUNCE ACTING CN COMPOSITE SYSTEM CM.C1711800
C
     PHI(1.K) = RESULTANT EXTERNAL TURQUE UN NEST K-1
```

```
C
            Me = MOMENTUN WHEEL LABEL
                                                                          C1712000
        DO (Pa) = BODY IN WHICH MCMENTUM WHEEL MW IS EMBEDDED
C
                                                                          C1712100
     HMC(I.Me) - COMPONENTS OF UNIT VECTOR ALONG SPIN AXIS OF WHEEL MM
C
                                                                         C1712200
C
                 (RELATIVE TO COMPUTING FRAME)
                                                                          C1712300
     GAM(I.KL) = COMPONENTS CF VECTUR FROM HINGE FOINT K-1 TO CENTER OF C1712400
c
                 MASS OF BODY L. WHERE KL = KTO(NUL.K-L.L)
                                                                          C1712500
C
       SKIK-1) = CODED WORD, ALL ECDIES IN NEST K-1
                                                                          C1712600
C
      SMC(K-1) = CODED BCRD, ALL MOMENTUM WHEELS IN NEST K-1
                                                                          C1712700
    XMC(1.J.L) = THANSFCHMATION MATRIX, EGDY L TO COMPUTING FRAME
                                                                          C1712800
c
C
    XMC(1,..0) = TRANSFCRMATICN MATRIX, INERTIAL TO COMPUTING FRAME
                                                                          C1712900
c
             Y = SOLUTION ARRAY. CONTAINS INTEGRATED PARAMETERS
                                                                          C1 71 3000
C
            YD = EQUATION ARRAY. SENT TO RUNGE FOR INTEGRATION
                                                                          C1713100
           NEC = NUMBER OF FIRST CROER DIFFERENTIAL EQUATIONS DEFINED
c
                                                                          C1713200
C
                 OUTSIDE OF SLERGLTINE TURQUE
                                                                          C1713300
C
                                                                          C1713400
C
                                                                          C1713500
c
                                                                          (1713600
C
                    INPUT OF USER REQUIRED DATA FOR SUBRUUTINE TORQUE
                                                                          C1 71 3700
C
                                                                          C1713800
C
             THE USER MAY APPLY CHE OF THREE CHTICAS
                                                                          C1713900
c
              1) PREFERABLE. DEFINE ALL USER REQUIRED DATA ON
                                                                          C1 71 40GO
C
                     'DATA' CAFDS AITHIN SUBROUTINE TURQUE
                                                                          C1714100
C
              2) WRITE SUBROUTINE INTOR AND PASS ALL USER REQUIRED CATACITIA200
c
                     THECUGH CCMMCN IN /SATELL/
                                                                          C1714300
c
              3) READ INPUT CATA ON FIRST PASS THROUGH TORQUE
                                                                          Ci 714400
                     CT4 = 1 CN FIRST PASS THROUGH, STORE DATA
C
                                                                          C1714500
C
                             IN /SATELL/
                                                                          C1714600
C
                                                                          C1714700
C
                                                                          C1714800
C
                                                                          C1714900
C
                                                                          C1715000
C
C
                    REACTION TORQUE ACTING ACRUSS OR ALONG GIMEAL AXIS MC1715200
C
                      AT HINGE PLINT K-1 DUE TO :
                                                                          C1715300
c
                      LINEAR SFRINGS
                                                                          (1715400
                      LINEAR VISCOUS DAMPERS
C
                                                                          C1715500
C
                      MCTCAS
                                                                          C1715600
C
      LFT:
                                                                          C1715700
        SPF(M) = SPRING CONSTANT ABOUT UN ALJNG GIMBAL AXIS M
C
                                                                          C1715800
                  (M+L++2/T++2 CR M/T++2)
                                                                          C1715900
C
C
       CP((F) = DAMPING CONSTANT ADOUT OR ALONG GIMUAL AXIS M
                                                                          C1716000
C
                  (M+L++2/T CR M/T)
                                                                          (1716100
        CLT(M) = CONTROL TORQUE AFPLIED BY MUTOR ABOUT OR ALGNG GIVEAL
C
                                                                          C1716200
C
                  AXIS M M+L++2/1++2 OR M+L/T++2
                                                                          C1716300
C
                                                                          C1716400
C
                         DIMENSION TEM(3)
                                                                          C1716500
C
                         SPRING TORQUE
                                                                          C1716600
C
                   C
                         SPR(M) = USER INPUT
                                                                          C17167CO
C
                         A = SFR(M)+THA(M)
                                                                          C1716800
c
                         CALL SCLV(A. OFC(1.M).TEM)
                                                                          C1716900
C
                         CALL VECSUS (PHI(I.K) .TEM.PHI(I.K))
                                                                          C1717000
C
                         DAMPER TORQUE
                                                                          C1717100
C
                   C
                         DPC(M) = USER INPUT
                                                                          C1717200
C
                         A = DFC(F)*THAD(M)
                                                                          C1717300
C
                         CALL SCLV(A.QFC(1.M).TEM)
                                                                          C1717400
C
                         CALL VECSLO(PHI(1.K).TEM.PHI(1.K))
                                                                          C1717500
C
                   C
                         MOTOR TORQUE
                                                                          C1717600
                         CLT(M) = FUNCTION OF STATE VARIABLES. LSER DEF.C1717700
C
                         CALL SCLV(CLT(M) .QFC(1.M).TEM)
                                                                          C1717800
C
                         CALL VECADO (PHI(I.K) . TEM . PHI(I.K))
                                                                          C1717500
```

```
C
                                                                          C1718000
C
                                                                          C1718100
C
                                                                          C1718200
C
C
                                                                          C1718400
C
                    REACTION TERQUES ON SYSTEM DUE TO A CONTROL TORGUE
C
                    APPLIED TO MOMENTUM WHEEL ME
                                                                          C171860C
C
      LET:
      CLM(Am) = CONTROL TORQUE APPLIED TO WHEEL MW ABOUT ITS SPIN AXIS (1718600
C
                USER DEFINED FUNCTION OF STATE VARIABLES (MeL++2/T++2) (1718900
C
                         CLM(Mb) = USER DEFINED FUNCTION OF STATE VARE. C1719100
C
C
                                                                          C1719200
C
                                                                          C1719300
c
                                                                          C1719400
C
                                                                          C1719500
C
                                                                          C1719620
C
                                                                         C1719700
C
                    REACTION TO LES UN SYSTEM DUE TO A LOCALLY
                                                                         C1719800
C
                    APPLIED EXTERNAL FUNCE (I.E. A GAS JET)
                                                                         C1 71 9900
C
      LET:
                                                                          C1720000
C
             J = INTEGER LABEL ASSIGNED TO GAS JET
                                                                         C1720100
             L = BUDY TO WHICH EXTERNAL FORCE DIRECTLY APPLIED
                                                                         (1720200
C
        RJ(1) = RADIUS VECTOR FROM CENTER OF MASS OF HODY L TO
                                                                         C172C300
C
                 GAS JET J. (COMPONENTS RELATIVE TO BODY L COORDINATES) C1720400
C
        FJ(1) = COMPONENTS OF APPLIED FUNCE DUE TO GAS JET J. (RELATVE C1720500
C
                TO BODY L CCCFDINATES) USER DEFINED FUNCTION OF STATE C1720600
C
                 VARIABLES (NOL/TOOZ)
                                                                         C1720700
c
                                                                         C1723800
C
              DIMENSION RJC(3).FJC(3).TEM(3).TEMI(3).RJ(3).FJ(3)
                                                                         C1720900
C
              INTEGER SI(10).NS1
                                                                         C1721000
c
              LUGICAL CTAIN
                                                                         C1721100
C
        C
              RJ(I) = LSER INFLT
                                                                         C1721200
C
              CALL VECTEN(RJ.XMC(1.1.L).RJC)
                                                                         C1721300
C
              FJ(1) = USER DEFINED FUNCTION OF STATE VARIABLES
        C
                                                                         C17214C0
C
              CALL VECTEN(FJ.XMC(1.1.L).FJC)
                                                                         C1721500
c
              CALL VECADD(PHI(1.NEI).FJC.PHI(1.NEI))
                                                                         C1721600
C
              DO 3 K=1.NBOD
                                                                         C1721700
              CALL UNPAC(SI.NEL.SK(K-1))
c
                                                                         C1721800
c
              IF( .NOT . CTAIN(L .SI .NS1)) GO TO 3
                                                                         C1721900
              IF(RBLO(K)) GC TC 4
                                                                         (1722000
C
              CALL VECADD(PHI(1.K).FJC.PHI(1.K))
                                                                         C1722100
C
              GO TO 3
                                                                         C1722200
c
             4 KL = KTO(NB1.K-1.L)
                                                                         C1722300
              CALL VECADD (GAN (1.KL) . RJC. TEM)
                                                                         C1722400
              CALL VECRES (TEN.FJC.TEMI)
C
                                                                         C1722500
C
              CALL VECACD(PHI(1.K), TEM1.PHI(1.K))
                                                                         C1722600
C
            3 CONTINUE
                                                                         C1722700
C
                                                                         C1722800
c
                                                                         C1722900
C
                                                                         (1723000
C
                                                                         C1723100
C
                                                                         C1723200
c
                                                                         C1723300
C
                    REACTION TORQUES ON SYSTEM DUE TO GRAVITATIONAL
                                                                         C1723400
                    EFFECTS CN AN EARTH EASED SYSTEM
                                                                         C1723500
C
Ç
      LET:
         GRAV = ACCELERATION CF GRAVITY (L/T++2)
C
                                                                         (1723700
C
        BF(1) = COMPUNENTS OF UNIT VECTOR FROM INERTIAL CHIGIN TO COPP.01723800
                SYSTEM CENTER OF MASS. (RELATIVE TO INERTIAL FRAME) C1723900
```

```
C
                 THAT IS. PARALLEL TO DIRECTION OF GRAVITY FURCE
                                                                           C17240C0
C
                                                                           C1724100
C
               INTEGER SI(10).ASI
                                                                           (1724200
               DIMENSION TEM(3).8FC(3).8H(3)
                                                                           C1724300
C
        C
               BH( I) = LEER INPUT
                                                                           C1724400
•
               CALL VECTEN (3F . XMC(1.1.0) . BHC)
                                                                           C1724500
                                                                           C1724600
C
               00 4 K=1.NEDC
                                                                           C1724700
C
               GRAV - LEER INPLT
         C
C
               A = XMAS(K) *GRAV
                                                                           C1724800
C
               CALL SCLV(A.BFC.TEN)
                                                                           (1724900
C
               CALL VECSUB(PHI(I.NOI).TEM.PHI(I.NOI))
                                                                           C172500C
C
               IF(RBLU(K)) GC TO 5
                                                                           C1725100
C
               CALL VECSUB(PHI(1.K), TEM, PHI(1.K))
                                                                           C1725200
C
               60 TO 4
                                                                           01725300
C
             E CALL UNPAC(SI .NEI .EK(K-1))
                                                                           C1725400
C
               DU 4 LL=1.NS1
                                                                           C1725500
C
                                                                           C1725600
               L = SI(LL)
C
              KL = KTO(NB1.K-1.L)
                                                                           C1 725700
C
               A = XMAS(L) .GSAV
                                                                           C1725800
C
               CALL SCL V(A. BEC.TEN)
                                                                           (172590)
C
               CALL VECKES (GAM(1.KL), TEM, TEMI)
                                                                           C1726000
C
               CALL VECSUE(PHI(I.K).TEMI.PHI(I.K))
                                                                           C1726100
C
            4 CONTINUE
                                                                           C1726200
C
                                                                           (172630)
C
                                                                           C1726400
C
                                                                           C1726500
C
                                                                           C1726600
C
                                                                           01726700
                    KEPLERIAN CHAIT
C
                                                                           C1726800
C
    LET:
                                                                           C1726900
     CE(1, )) = COMPUNENTS OF VECTOR FROM EARTH'S CENTER TO COMPOSITE (1727000
C
                 SYSTEM CENTER OF MASS. RELATIVE TO INERTIAL PEFERENCE (1727100
C
                 FRAME, ORBIT ASSUMED TO BE IN INERTIAL 2-3 PLANE
C
                                                                           C1727200
          ASM = SEMI-MAJOR AXIS OF ELLIPTIC DROLT INERTIAL 2 DIRECTION (1727300
C
          ECC = DRUIT ECCENTRICITY
                                                                           C1727400
           THE = TIME OF PERIFELICA PASSAGE. (T)
C
                                                                           C1727500
C
           GEV = EARTH'S GRAVITATIONAL CUNSTANT, (L++3/T++2)
                                                                           C1727600
•
          ETE = MEAN MCTICN
                                                                           C1727700
C
          AME = MEAN ANCMALY
                                                                           01727400
C
           ECE = ECCENTRIC ANCHALY
                                                                           (1727900
C
           TVE = TRUE ANCHALY
                                                                           C1 72 8000
C
          BIC = MAGNITUDE OF CE(1.3). (L)
                                                                           (1728100
C
                                                                           C1728200
C
                                                                           C1728300
C
       C
               ASM = USER INPLT
                                                                           C1728400
C
        C
               GEV = USEF INFLT
                                                                           C1728500
C
               ETE = 1./50+ T(ASN . . 3/GEV)
                                                                           C1728600
C
        C
               TPP = USER INFUT
                                                                           C1728700
C
               AME = ETE . (T-TFF)
                                                                           C1728800
C
               SMI = SIN(AME)
                                  : SM4 = SIN(4+AME)
                                                                           C1720900
C
               SME = SIN(2 AME)
                                                                           C1 72 9000
C
               SM3 = SIN(3+ANE)
                                                                           .1729100
C
        C
               ECC = USER INFUT
                                                                           C1729200
               ECE = AME + ECC+SM1 + ECC++2+SM2/2
C
                                                                           C1729300
C
                    +ECC++3+($+5M3 - 3+5M1)/(24)
                                                                           C172940C
C
                    +ECC++4+164+5M4 - 32+5M21/192
                                                                           C1729500
C
               CL = COSTECE)
                                                                           C1729600
C
               SE = SIN(ECE)
                                                                           C1729700
              BTO = ASMA(1 - ECC+CE)
C
                                                                           (1729800
C
              CB(1.0) = C
                                                                           (1729400
```

```
C8(2.0) = BTO+((CE- ECC)/(1 - ECC+CE))
                                                                         C1730000
              CB(3.0) = BTO*(SGRT(1-ECC**2)*SE/(1-ECC*CE))
C
                                                                         C1730100
                                                                         C1730200
              CALL VECTRN(CE(1.0).XMC(1.1.0).CBC(1.0))
C
                                                                         C1730300
C
                                                                         C1730400
C
                                                                         C1730500
C
                                                                         C1730600
C
                                                                         C1730700
C
                    REACTION TERGLES ON URBITING SYSTEM DUE TO
                                                                         C1730800
C
                         GRAVITY GRADIENT EFFECTS
                                                                         C: 730900
C
     LET:
                                                                         C1731000
C
     CAC(1.1) = COMPONENTS OF VECTUR FROM COMPOSITE SYSTEM CENTER OF
                                                                         C1731100
C
                 MASS TO CENTER OF MASS OF BUDY 1. HELATIVE TO
                                                                         C1731200
C
                 COMPUTING FRAME
                                                                         C1731300
    . NOTE FOR GRAVITY GRADIENT CFTICN
C
                                                                         C1731400
C
    . CE(1.1) AND ITS INERTIAL DEHIVATIVE
                                                                         C1731500
C
     A ARE REDEFINED TO CIRCUMVENT DIFFERENCE
                                                                         C1731500
C
     . OF LANGE NUMBER PROPLEMS. THAT IS
                                                                         C1731700
C
     4 THEY ARE MEASURED FROM COMPOSITE OM TO
                                                                         C1731800
C
     . CH CF BCDY I RATHER THAN FROM INERTIAL
                                                                         (1731900
C
     . CRICIN TO CM OF BCDY 1
                                                                         C1732000
C
        BF(1) = UNIT VECTOR FROM EARTH'S CENTER TO SYSTEM COMPOSITE
                                                                         C1732100
                 CENTER OF MASS, COMPUNENTS RELATIVE TO INERTIAL FRAME (1732200
C
C
     CEL(1.x) = COMPONENTS OF VECTOR FROM COMPOSITE SYSTEM CENTER OF
                                                                         C173230C
                 MASS TO CENTER OF MASS OF BUDY K
C
                                                                         C1732400
     DFG(1,k) = COMPONENTS OF GRAVITY GRADIENT FORCE ACTING ON BODY K C1732500
C
       SGG(1) = COMPACTED INTEGER WURD, THUSE BODIES IN THE NEST I
C
                                                                         C173260C
                WHICH SIGNIFICANTLY CONTRIBUTE TO GRAVITY GRADIENT EFF. 01732700
c
C
          BTC = DISTANCE FROM EAFTH'S CENTER TO COMPOSITE SYSTEM CP
                                                                        C1 732800
C
                                                                         C1732900
C
               DIMENSION DEL (3,10).DFG(3,10),JHC(3).HH(3).TEM(3).TEM(3)C1733000
              INTEGER SGG(C.9). 51(10)
C
                                                                         C17331CC
C
              KEPLERIAN ORBIT NUST de USEC WITH GRAVITY GRADIENT CFTIONC1733200
C
                                                                         C1733300
              DU 10 1=1.3
C
           10 8HC(1) = CBC(1.C)/ETO
                                                                         C1733400
C
              DO 7 K=1.NHOD
                                                                         (1733500
C
              KL = KTO(ABI.C.K)
                                                                         C1733600
C
              CALL VECADD (CEC(1.1). JAM(1.KL).DEL(1.K))
                                                                         C1733700
C
              CALL VECDCT(BHC.CEL(I.K).A)
                                                                         C1733800
C
              A = 3.A
                                                                         (1733900
C
              CALL SCLV(A.SHC.TEN)
                                                                         C1734000
¢
                                                                         C1734100
              CALL VECSUB(DEL(1.K). TEM. TEM)
C
              A = -GEV+>MAS(K)/BTO++3
                                                                         C1734200
C
              CALL SCLV(A.TEP.DFG(1.K))
                                                                         C1734300
C
           7 CONTINUE
                                                                         C1734400
C
              DO 8 K=1.NBCD
                                                                         C1734500
C
              FERBLOCKI) GC TC S
                                                                         C1734600
C
              LALL VECADO (PHI(1.K). DF 3(1.K). PHI(1.K))
                                                                         C1734700
C
              GO TU B
                                                                         C1734800
C
             SGG(1) = SK(1) IF ALL BUDIES CONTRIBUTE TO GRAVITY GFAC. C1734900
                             EFFECTS. IF NUT USE COMPAC TO CONSTRUCT
       C
C
                                                                        C1735000
C
                              SEG(I) FORM USEN INPUT OR DEFINE CIRECTLY C1735100
            S CALL UNPAC(SI .NEI .SGG(K-1))
                                                                         C1735200
C
C
              DO 8 LL=1.NS1
                                                                         C1735300
                                   A C. T. J. W. A. C. A. F. J. W. March
                                                                   11 1 (1735400
c
              L = SI(LL)
C
              KL = KTO(NHI.K-I.L)
                                                                         C1735500
              CALL VECTCS (GAM(1.KL).DFG(1.L).TEM)
C
                                                                         C1735600
              CALL VXDYCV(8+C.XIC(1.1.L).TEM1)
                                                                        C17357C0
                                                                        C1735800
C
              A = 3.GEV/ETC..3
              CALL SCLV(A.TEMI.TEMI)
                                                                         C1 735900
```

```
CALL VECACC(TEN.TENI.TEM)
                                                                           C1736000
C
                                                                           C173610C
C
               CALL VECACD(PHI(1.K).TEM.PHI(1.K))
                                                                           01736200
C
             & CUNTINUE
                                                                           C1736300
C
                                                                           C1736400
C
C
                                                                           01736500
                                                                           C1736600
C
                                                                           01736700
C
c
                                                                           C1736800
                                                                           C1736900
C
                    PARAMETERS CEFINED BY FIRST UNDER
                      DIFFERENTIAL EJUATIONS
                                                                           C1737000
C
C
      LET:
                                                                           C1737100
           NTG = TOTAL NUMBER OF FIRST ORDER DIFFERENTIAL EQUATIONS TO (1737200
C
C
                 BE SOLVED FOR USE IN SUBRUUTINE TURQUE
                                                                           C1737300
         TC(N) = MAGNITUCE OF FARAMETER NUMBER N CEFINED WITHIN SLE.
                                                                           C1737400
C
                 TORQUE AT TIME T
C
                                                                           C1737500
        TOCIN) = TIME DEHIVATIVE OF PAHAMETER TO(N). A USER DEFINED
                                                                           C1737600
C
                 FUNCTION OF THE SYSTEM'S STATE VARIABLES
C
                                                                           C1737700
C
                                                                           C1737800
C
                         DIMENSION TO(20) . TOD(20)
                                                                           C1737900
C
                   C
                         FOR THE PARAMETER N
                                                                           C1738000
                          IF(CT4.NE.1) 50 TU 11
C
                                                                           C1738100
C
                          Y(NEG+N) = TU(N) = INITIAL VALUE FOR TG(N)
                                                                           (1738200
C
                      11 TG(N) = Y(NEJ+N)
                                                                           C1738300
                          TOD(N) = USER DEFINED FUNCTION OF STATE VARB.
C
                                                                           C1738400
C
                   C
                                                                           C1738500
                          AFTER CEFINITION OF LAST DIFFERENTIAL EQUATION C1738600
C
                   c
                         NTO = TOTAL NUMBER OF FIRST URDER DIFFERENTIAL C1738700
C
                   C
C
                   C
                               ECLATIONS TO BE SOLVED FOR USE IN TEROLE C1738800
C
                          DTM . 1 = N S1 DO
                                                                           C1738900
                      12 YO(NEC+N) = TQJ(N)
                                                                           C1739000
C
C
                                                                           C1739100
C
                                                                           C1739200
C
                                                                           C1739300
                                                                           C1739400
C
C
                                                                          C1739500
C
                     THERMALLY INDUCED MOTION ABOUT GIMBAL AXIS M
                                                                           C1739600
C
                      AT HINGE POINT K-1
                                                                          C1739700
C
      ASSUNE:
                                                                           C1739800
C
             ALL THERMALLY INDUCED DEFLECTION IS SMALL ANGLE
                                                                          C1739900
                RELATIVE TO THE SYSTEM'S NUMINAL ZERU STRESS STATE
C
                                                                          C1740000
C
             THERMALLY INDUCED DEFLECTION IS MODELLED AS A MOVEMENT
                                                                          C1740100
C
                OF THE ZENC STRESS STATE
                                                                           C1743200
             ACROSS ALL HINGE FCINTS SUBJECT TO THERMAL DEFORMATION
C
                                                                          C1740300
C
                SPRINGS AND CAMPERS ACT
                                                                          C1740400
C
             A RESCHABLE MODEL OF THE THERMAL INPUT CAN BE DEFINED
                                                                           C1740500
C
                IN TERMS OF THE SYSTEM'S STATE VAHIABLES
                                                                           C1 74 0600
C
             THERMAL EQUILIBRIUM FOSITION ADOUT ANY GIMBAL AXIS IS DEF. C174C700
                BY SOLUTION OF THE HEAT CONDUCTION EQUATION
                                                                           C174080C
C
C
     LET:
                                                                          C1740900
         SFR(F) = SPRING CONSTANT ACROSS GINHAL AXIS M
                                                                          C1741000
C
         DFC(N) = DAMPING CONSTANT ACROSS SIMBAL AXIS M
                                                                           C1741120
C
         TAU(M) = THERMAL TIME CONSTANT FOR DEFORMATION ABOUT GIMEAL
                                                                          C1741200
C
                  AXIS P. (T)
                                                                           C1741300
C
  TG(N) = THERMAL EQUILIBRIUM POSITION FOR THERMAL DEFORMATION
                                                                          C1741400
C
C
                 ABOUT GIMBAL AXIS M. (RAD)
                                                                           C1741500
C
       TGE(N) = RATE UF CHANGE OF THERMAL EQUILIBRIUM POSITION ABOUT
                                                                          C1741600
                 GIMHAL AXIS M. FIRST UNDER DIFF. EQ., (HAD/T)
                                                                          C1741700
C
        TIMP = THERMAL INPUT USER DEFINED FUNCTION OF STATE VARIABLES. C1741800
C
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(RAD/T)

C1741900

```
C1742000
C
C
               DIMENSION TEM(3)
                                                                           C1742100
C
         C
               N = USER DEFINED LABEL, DEPENDS UPON EQUATION NUMBERING C1742200
                    SEQUENCE DEFINED WITHIN SUBROUTINE TORQUE
                                                                           C1742300
C
         C
               IF(CT4.NE.1) GU TO 13
c
               Y(NEQ+N) = TQ(N) = INITIAL VALUE FOR THERMAL DEFORMATION C1742500
c
         c
c
                                   ABOUT GIMBAL AXIS M. USER INPUT
         C
C
            13 TO(N) = Y(NEC+N)
                                                                           C1742700
C
         C
               TINP = USER DEFINEC THERMAL INPUT FUR THERMAL CEFCRMATICN (174280C
C
        C
                      ARCUT GINEAL AKIS M
c
         C
               TAU(M) = LSER INFLT
                                                                           C1743000
C
               TOD(N) = -TO(N)/TAL(M) + TINP
                                                                           C1743100
C
               A = SPR(M)+(THA(M) - TQ(N))
                                                                           C1743200
c
               LALL SCLV(A.OFC(1.N).TEM)
                                                                           C1743300
c
               CALL VECSUB(PHI(1.K).TEM.PHI(1.K))
                                                                           C1743400
C
               A = DPC(+)+THAC(M)
                                                                           C1743500
C
               CALL SCLV(A.QFC(1.P).TEM)
                                                                           C1743600
c
               CALL VECSUB(PHI(1.K).TEM.PHI(1.K))
                                                                           C1743700
C
                                                                           C1 74 3800
c
                                                                           C17439CO
c
                                                                           C1744000
C
                                                                           C1744100
c
                                                                           C1744200
C
                                                                           C1744300
C
                                                                           C1744400
C
      ZERO ALL ELEMENTS OF EXTERNAL TURJUE MATHIX
                                                                           C1744500
      CO 1 K=1.N01
                                                                           C1744600
      CC 1 1=1.3
                                                                           C1744700
    1 PHI(1.K) = 0.DO
                                                                           C1744800
      CO 2 N=1.NMU
                                                                           C1744900
    2 CLM(F) = 0.DO
                                                                           C1745300
C
                                                                           C1745100
      FETUEN
                                                                           C1745200
      ENC
                                                                           C1745300
                                                                           CIECOCCC
C
                                                                           00100813
      SUFREUTINE OFDET
        LSED TO REDUCE THE SET OF NEUD+1+NMV VECTOR DYACIC EQUATIONS OF (1800200
C
         MCTICK TO NFER+NMV SCALAR EQUATIONS
C
C
                                                                           C1822400
C
                                                                           C18005CC
C
         SCF(K) = LOWEST MAGNITUDE FREE COUNDINATE INDICE AT HINGE
                                                                           C1800600
                  POINT K-1. EQUALS ZERU IF THREE CUNSTRAINTED AXES
                                                                           C1800700
         SGL(K) = LOWEST MAGNITUDE LOCKED COURDINATE INDICE AT HINGE
                                                                           00900910
C
                  PUINT K-1. EGUALS ZERG IF THREE FREE AXES
                                                                           C1 EC0900
C
         SCK(K) = BODY LABELS ON FATH FROM HINGE POINT ZERO TO C.M.
                                                                           C1601000
                  OF BUDY K. FCR K=NBI IT IS SET OF ALL ECDY LABELS
C
                                                                           C1801100
                                                                           C1801200
      IMPLICIT REAL+8(A-H.O-Z.S)
C
                                                                           C18013C0
                                                                           C1801400
C
      LOGICAL FG1 . FG2 . FG3 . FG4 . F ib . INERF . MBLO . LEQU . LINIT(1)
                                                                           C1831500
                      LALNGE . LTRASI . LVDIV . LEQUIV . LTRAN .
                                                                          C1801600
     LOGICAL
                      LTRANV . LRATE . LXDY
                                                . LETA
                                                        . LTOPQU .
                                                                           C1801700
                      LGFDOT . LDCT . LANGLE . LSETUP . LSIMO
                                                                          C1801800
                                                                           C16C19C0
C
```

C1802000

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INTECEN
                                                                           C1802100
     * ANDFK . CT1 . CT2 . CY3 . CT4 . CT5 . FCON . PCCN . C1892200
     * SCNDUM, SCN , SCRDUM, SCR , SFKDJM, SFK , SFR , SG , C1602300

* SI , SIG , EIXDUM, SIX , SKDUM , SK , SL , SLK , C1802400

* SMA __SMCDUM, SMC , SMV , SUK , SPIDUM, SPI , SQF , C1802500
            . SR . SSCN . SSIX . SVA
                                                               . SVI
                                                                        . 01602600
     * SCL
                                               . SVB . SVD
                     . SVQ
                                      . SXT
     * SVM . SVP
                              . SXP
                                              . TORU . SMAL . SEU . C1802700
                    . NFLXB . SFLX
     * SC
             . SCG
                                      . SFXM . NMCDS . SFCC . SCC . C1802800
     * IINIT(1)
                     . IZINIT(1)
                                      . SD
                                              . SCXC(20)
                                                                            (1802900
                                                                            C1803000
C
                                                                            C180310C
      SEAL OH
                                                                            C1E03200
     * ANGE (33) . CNF (3.10) . ETIC (3.10) . ETMC (3.10) . C1603300

* FLQ (3.20) . FLE (3.3.20). FLH (3.3.20). C1603400

* THACD (33) . YMCD (3.2.11). RINIT (1) . HZINIT(1) C1803500
C
                                                                           C1803600
c
                                                                           C1803700
      COMMEN /LDEBUG/ LRUNGE , LTRNSI , LVDIV , LEQUIV , LTRAN , LTRAN , LTRAN , LXDY , LETA , LTURQU .
                                                                           C1 E0 3800
                                                                           0.001000
                      LGFDOT . LDCT . LANGLE . LSETUP . LSIMO
                                                                           C1804C00
C
                                                                           C1804100
C
                                                                           C1804200
     COMMEN /LUGIC/ FG1. FG2. FG3. FG4. FG5. INERF. RHLJ(10)
                                                                           C1804300
C
                                                                           C1804400
C
                                                                           C1804500
      CCMMCN /INTG/ ANOHK(200) .
                                                                           C1 E 04 6 0 0
     * C 11
                                      . CT3
                                                                        . C1604700
                      · CT2
                                                      . CT4
                                      . JCCN (10)
                                                                        . C1804800
                     . FCON (33)
                                                      . LCON (22)
     • C15
                                                                     · C1804900
     . MC
           (10)
                     . NE1
                                      . N303
                                                      . NCTC
                     . NFKC
                                      . NFRC
     * NFEF
                                                      . NLOR
                                                                     4
                                     . NMOA
                     . NHC
                                                      . NSVP
     * NHV
                                                                           C1895100
                     . PCON (11)
                                                      . SFR (33)
     * NEVC
                                      . 50
                                                                           (1605200
                                                      . SL
     * SG
                     . 51
                                      . 516
                                                                        · C1E05300
                             (55)
     * SLK
           (33) , SMA
(11) , SMV
                                      , SOK (11) . SQF (11) . C180540C
                              (10)
                                                      . SSCN
                                      . SR
     * SGL
                                                                        . 01805500
     . SSIX
                     . SVA
                                      . SVB
                                                      . SVD
                                                                           CLECSECO
     * SVI
                     . SVM
                                      . SVP
                                                      . SVG (33)
                                                                        . (1605700
                                              (22)
                                      . TORQ (97)
                                                      . SMAL
                                                                        . (1805800
     • SXM (3.10) . SXT
                     . ATQ
                                      • SC (33)
• SFXM (10)
                                                                        . 01805900
                                                      . SCG
     • SEU
     * NFL X3
                     . SFLX
                                                      . NMCDS
                                                                           C1609000
     * SFCC
                     . SCC (10)
                                                                           C1806100
C
                                                                           C1806200
C
                                                                           C18C6300
     CENMEN /INTGZ/
                                                                           C18C6400
                                                     . SCR (9)
     SCNEUM . SCN
                              (5)
                                     . SCRDUM
                                                                        . (1876500
                     . SFK
                                                     . SIX
     * SEKCUM
                              (5)
                                      . SIXDUM
                                                             (9)
                                                                        . 01806600
                     . SK
                                                     . SPI
                                                                        . (1806700
     * SKOLM
                              (5)
                                       . SPIDUM
                                                              (9)
                     . SMC
     . SMCCUM
                              (5)
                                                                           C1806800
C
                                                                           C1806900
                                                                           C1807000
     COMMEN /FEAL/
                                                                           C1607100
                                              (10) . CCMC (3.11) . C1807200
(33) . FUMC (3.11) . C1807300
     * CA (3.10) . CAC
* DCMC (2.11) . ETC
                              (3,10) . CLM
(3,11) . ETM
    . DCMC
                                                               (3.10) . . (1807400
     . GAM (3.60) . F
                                      . HM
                                               (3.10) . HMC
           (10) , PFI
(3,33) , QL
    .. HNON
                              (3.11) . PLM
                                               (10)
                                                      . GF
                                                               (3.33) . C1607500'
                                                      . FOMC (3.11) . C1807600
     · QFC
                             (3.22) . QLC
                                               (3,22)
                                                      . THAU (33)
     * T
                                       THA
                                               (33)
                                                                           C1607700
                    . THAW (10)
                                                               (3,3,1C) . C1807800
     * THAC* (10)
                                      . XDIC (3.3.06) . XI
                                                             (3.3.1C). C18C7900
     * XIC (3,3,10), XMAS (10)
                                      . XMN (33.33) . XMT
     * TLG (33) , FLA (3.20) , FLD (3.20) , FLC (3.20) , C1608000
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* FLD (3,3,20), FLJ (3,3,20), CAC (3,10) , XIO (3,3,10), (1698100 
* FLIRC (3,10) , FLCRC (3,10) , FLAC (3,20) , FLQC (3,20) , C1898200
      * FLC* (20) , ZETA (20) , FCF (3.3.40), FCK (3.40) , C1898300
      * TIMEND
                                                                             C1608400
                                                                             CIRCASCO
0
                                                                             00380913
                                                                             C18C6700
      COMMEN /FEALZ/
                               (3.10) . CBCDJ4(1.3) . CHC
      * CEDLM (1.3) . CE
                                                                (3.1C) .
     * XMCCLM(1.1.9) . XMC (3.3.13). CBN(3)
                                                                             C1808900
C
                                                                             0100000
                                                                             01609100
C
      EQUIVALENCE (ETM(1). THADE(1))
                                               . (XMN(1.1). ANGD(1))
                                                                             C1609200
                                               .(XMN(1.6).CNF(1.1))
                   (XMN(1.3).YMCD(1.1.1))
                                                                            C1829300
                                                                           C1809400
                   (XMN(1.8).ETIC(1.1))
                                               .(XMN(1.10).ETMC(1.1)) .
                                               .(FLE(1,1,1).FLD(1,1,1)).
                                                                            C1 EC9500
                   (FLB(1.1).FLQ(1.1))
                   (FLH(1.1.1).FLJ(1.1.1))
                                                                             C1#3960C
     *
                   (FG1.LINIT(1))
                                               .(CA(1.1),RINIT(1))
                                                                             C1809700
                  (C2DUM(1.1).HZINIT(1))
                                              . (AWCHK(1). IINIT(1))
                                                                            0.0860810
                                              .(TORG(73).SCXC(1))
                                                                             C1809900
                  (SCNDUM.IZINIT(1))
C
                                                                             20001313
C
                                                                             C1610100
C
                                                                             C1610200
C
                                                                             C1610300
      CINENSICK TEM1(3) . TEM(3.11) . X33(3.11)
                                                                             C1810400
      CINENSILA TEM2(3) . TEM3(3) . FTEM(J) . FLHC(J.3)
                                                                             C1613500
      CIMENSICK EGFC(99), EXCIC(554)
                                                                            C1810600
      FEAL +d
               FCUP(3.3.20) .FCLP1(3.3) .KCUP(3.20) .KCUP1(3)
                                                                            CIELOZOC
                TMF(3,3), TMK(3)
                                                                            CLEIGHOO
      RE AL .
      INTEGER STICIC). 512(10). ST3(11)
                                                                             C1813900
      INTEGER STACED
                                                                             C1811C00
      INTEGER SFXMN
                                                                             C1811100
      LUGICAL CTAIN
                                                                             C1611200
      EQUIVALENCE (DCMC(1.1).TEM(1.1)), (EUFC(1).GFC(1.1)),
                                                                             C1E11300
                   (EXDIC(1).XDIC(1.1.1))
                                                                             C1811400
                                                                             CLELISOC
      EATA IH/4HXMN(/
      EQUIVALENCE (LGFDCT.LEGU)
                                                                             01811600
                                                                             C1 61 1 700
C
C
                                                                             01811800
      IF (LEGU)FRINT 226
                                                                             C1811900
      ZERC ALL ELEMENTS IN AMM MATRIX
C
                                                                            C1 81 2000
      ATERN = NEER + NMV + NMODS
                                                                             C16121C0
      CO IE N=1.NTERM
                                                                             C1812200
                                                                            C1P12300
      CO LE MEN.NTERM
      XMN( N . N ) = 0
                                                                             C1812400
   1E CONTINUE
                                                                             C1F12500
      IF (LEGUIPHINT 214
                                                                             C1812600
C
                                                                            C1E12700
      CYCLE THROUGH ALL ROWS OF SYSTEM INERTIA MATRIX
C
      COMPLTE (NEER) X(NEER) MATRIX OF SCALARS LEFT HAND SIDE OF SYSTEM C181290C
C
C
         MATRIX EQUATION OF MOTION
                                                                             01813000
                                                                            C1813100
      CO 7 K=1.N31
C
      CHECK FOR 3 CONSTRAINED AXES
                                                                            C1813200
                                                                            C1 81 4400
      IF (PCLN(K).NE.3) GC TO 21
                                                                            C1813400
      IF (LEGU)FRINT 227
                                                                            C1613500
      IF (LEGUIPHINT 202 . K
      IF (LEGUIFRINT 227
                                                                            C1613600
                                                                            C1813700
      GO TC 7
                                                                            C1813800
C
   21 CONTINUE
                                                                            C1E13900
      (ALL UNPACISTS . NST3 . SCK(K))
                                                                            C1814000
```

```
C1814100
       GET NON-ZERO ELEMENTS IN ROW K UF XDIC
c
      IF (LEQU)FRINT 227
                                                                              C1814200
      IF (LEGU)FRINT 205. K. (ST3(1).1=1.NST3)
                                                                              C1814300
                                                                              C1814400
      IF (LEGU)PRINT 228
                                                                              C181450C
      IF (NST3.EQ.0) GO TC 41
                                                                              C1814600
      CO 4C II=1.NST3
                                                                              C1814700
      I = ST3(11)
                                                                              C1814800
      MBEG = SUF (K)
      ABEG=SUF(I)
                                                                              C1814900
                                                                              C1815000
      MTERM=SCF(K)+2-PCCN(K)
                                                                              C1E15100
      ATERN=SGF(1)+2-PCCN(1)
                                                                              01815200
      IF (MEEG. GT. MTERM) GO TO 43
      CO 42 MENBEG , MTERM
                                                                              C1815300
      IF (NEEG. CT . NTERM) GO TC 45
                                                                              C1 E1 5400
                                                                              C1E15500
      CO 44 N=NBEG . NTERM
      IF (N.GT.N) GO TO 44
                                                                              C1815600
                                                                              C1 61 5700
      KI = KTI(Nd1.K.I)
                                                                              01815800
      NE = 3*(N-1)
                                                                              C1 81 5900
      NE = 3+(N-1)
      KIE = 9*(KI-1)
                                                                              C1 E1 6000
      CALL VUCYUV(QFC(1.M), XDIC(1.1.KI), GFC(1.N), XMN(M.N))
                                                                              C181610C
C
      REFLACE MULTI-SUBSCRIPT CPERATION WITH SINGLE SUBSCRIPT
c
                                                                              C1616200
                                                                              C1616300
       CEMPUTATION OF VECTOR BET BYAD DOT VECTOR
      CO 10 J=1.3
                                                                              C1816400
      TEMI(J) = EXDIC(KIE+J)*EGFC(NE+1) +
                                                                              C1 E1 6500
                 EXDIC(KIE+3+J)*EGFC(NE+2) +
                                                                              C1616600
                                                                              C18167CC
                 EXDIC(KIE+6+J) *EQFC(NE+3)
   IC CONTINUE
                                                                              C1 81 6800
                                                                              02691912
      XMN(N,N) = ECFC(ME+1)*TEN1(1) +
                                                                              C1E17000
                  EGFC(ME+2) + TEN1(2) +
                                                                              C1817100
                  EQFC(ME+3) *TE+1(3)
      IF (LEGU) PRINT 206. M.N.M.KI.N.M.K.I.N.XMN(M.N)
                                                                              C1E17200
   44 CENTINUE
                                                                              C1 81 7300
                                                                              C1 E1 7400
   45 CONTINUE
                                                                              C1817500
   42 CONTINUE
                                                                              C1817600
   43 CENTINUE
                                                                              C1E17700
   40 CENTINUE
                                                                              C1817800
   41 CENTINUE
                                                                              C1817900
    7 CONTINUE
                                                                              C1818000
C
                                                                              00181910
C
c
                                                                              C1E18200
      INCLUDE FLEXIBILITY TERMS
                                                                              C1618300
C
      IF (NFLXH.EU. C) GU TO 11
                                                                              C1618400
                                                                              C1818500
C
      (ALL UNPAC(STI.NSTI.SFLX)
                                                                              C1 81 8600
                                                                              C1E18700
      CALL UNPAC(ST4.NST4.SFCC)
                                                                              C1618800
C
      ZERO CUT GYROSCOPIC TORGUE ARRAY ETM(M). 4=NFER+1.....NFER+NMOCS
                                                                              C1818900
C
      NF1 = NFER + 1
                                                                              C1819000
                                                                              C1619100
      NF2 = NFEH + NMODS
      CO 17 M=NF1.NF2
                                                                              C1 E1 9200
      IF (LEGU) PRINT 252. M
                                                                              C1819300
                                                                              C1819400
   17 ETM(#) = 0.
                                                                              C1 £19500
      CYCLE THRU ALL NESTS. FCF K=1 PICK UP DIAGONAL AND MOST OF
                                                                              C1819600
C
      RICHT HAND SIDE OF EQUATION
                                                                              C1 81 9700
                                                                              C1619800
      CO 3 K=1.NHUC
                                                                              C1 81 9900
      CALL UNFAC(ST2.NST2.SK(K-1))
                                                                              0102000
      MA = 0
```

```
CO 3 NN=1.NST1
                                                                            C1620100
      A = STI(ASTI+I-NN)
                                                                            C1 F2 02 00
C
      CHECK IS BODY N A FLEXIBILE BODY IN NEST K-1
                                                                            C1 62 0300
      IF (CTAIN (N.ST2.NST2)) CC TO 4
                                                                            C1E20400
      PN = MN+SFXM(N)
                                                                            C1820500
      GU TC 3
                                                                            C1820600
    4 CONTINUE
                                                                            C1 E20700
      IF (.NOT.LEGU) GO TO SCCC
                                                                            C1 E2 0 8 0 C
                                                                            C1 62090C
      KM1 = K-1
      FRINT 234. N.KMI
                                                                            01621000
 500C CONTINUE
                                                                            C1821100
C
                                                                            01621200
      FOR K=1 GET: 1)DIAGONAL ELEMENTS OF XMN(M.N)
C
                                                                            01621300
c
                    2) CENTRIPITAL ACC. OF UNDEFORMED CM OF BODY N
                                                                           C1821400
c
                    3) MAJCR PCRTICK OF ETM(M)
                                                                            C182150C
c
                       M=NFER+1....NFER+NMCDS
                                                                            C16216C0
C
                                                                            C1821700
      IF (K.NE.1) GO TO 5
                                                                            C1821800
      TEM2(1) = 0.
                                                                            C1E21900
      TEM2(2) = C.
                                                                            C1822000
      TEM2(3) = 0.
                                                                            C1822100
      IF (LEGU) PRINT 241
                                                                            C1622200
c
      CENTRIPITAL ACCELERATION UNDEFURMED POSITION OF BODY N CM.
                                                                           C1 E22300
      N = 14
                                                                            C1822400
      IF (NI.EC.1) GO TO 12
                                                                            C1 £22500
      CALL VECTRN(CAG(1.NI).XMC(1.1.NI).TEM3)
                                                                            01655900
      IF (LEQU) PRINT 211. NI.NI.NI
                                                                            C1822700
      CALL TRIPVP(FOMC(1.NI).TEM3.TEM2)
                                                                            C1 622800
                                                                            C1 F22 900
      IF (LEGU) PRINT 212. NI.NI.NI
   32 JAI = JCEN(NI)
                                                                            01623000
      CALL TRIFVP(FCMC(1.JNI),CBC(1.NI),TEMJ)
                                                                           C1823100
      CALL VECADD(TEM2. TEM3. TEM2)
                                                                           C1823200
      IF (LEQU) PRINT 213. JNI.JNI.NI
                                                                           C1 82 3 3 0 0
                                                                           22465
      INL = IA
      IF (NI.NE.1) GC TO 32
                                                                            C1 E23500
   12 (ALL SCLV(XMAS(N).TEM2.TEM2)
                                                                           C1 F2 3600
      IF (LEGU) PRINT 222, N. (TEM2(J).J=1.3)
                                                                           C1 E2 3700
                                                                           CLESSHOD
    5 CONTINUE
C
C
                                                                            C1 62 4000
                                                                           C1E24100
c
      CYCLE THRU ALL FLEXIBLE ECDY MUDES ASSOCIATED WITH BUDY N IN
C
                                                                           C1824200
       THE NEST K-1. FOR K=1 DE EXTRA CEMPUTATIONS
                                                                            C1 E24300
c
C
                                                                            C1824400
      SEXUN = SEXM(N)
                                                                            C1 824500
      CC 3 11=1. SF XMN
                                                                            C18246C0
      MN = MN+1
                                                                            C1 E24700
                                                                            01824800
      . = NFER + MN
      COMPLIE VECTOR ELEMENTS OF F MATRIX AS NEEDED DON'T STORE IN
C
                                                                           C1 E24400
      COMMEN. STORE AS NEEDED IN FREM TO SAVE STORAGE
                                                                            01625000
      KN = KTC(NB1.K-1.A)
                                                                            C182510C
      (ALL SCLV(XMAS(N).GAM(1.KN).TEM3)
                                                                            C1825200
      (ALL VECROS(TEM3.FLAC(1.MN).FTEM)
                                                                            01625300
                                                                            C1825400
      CALL VECADD(FTEM.FLQC(1.MA).FTEM)
                                                                            C1825500
      IF (.NCT.LEGU) GO TO SOCI
                                                                           C1625600
      KM1 = K-1
      FRINT 235, KM1.N.MN.N.KM1.N.MN.MN.(FTEM(J).J=1.3)
                                                                            C1825700
                                                                           C1 E2 5800
5001 CONTINUE
                                                                           C1 E25900
      IF (K .NE . 1)GC TO 19
                                                                           C1626000
      (ALL TENTHN(FLH(1.1.MN).XMC(1.1.N).FLHC)
```

```
IFT . NOT . LEQUI OU IC 5002
                                                                           C1626100
     PRINT 248
                                                                           01826200
     FRINT 250.
                          (FLFC(1.1).1=1.3)
                                                                           01826300
    FRINT 253. MN.N.MN.N. (FEEC(2:11:1 1.1)
                                                                           1826400
     FRINT 25C.
                        (FL+C(2.1).1=1.3)
                                                                           01826500
SOTE CENTINUE
                                                                           C1826600
  15 CENTINUE
                                                                           01826700
                                                                           01826800
     CORPLIC ELEMENTS OF SMA ARRAY
                                                                           01126400
                                                                           C1+27006
     IF (LEGU) PRINT 22E
                                                                           11627100
     IF IPCCN(K) . EG. J) GC TH 44
                                                                           F1827200
    NI = sur (K)
                                                                           01827300
                                                                           C1F27400
     N2 = = = + (K) + 2 - FCCN(K)
     EP 6 L=NI.Nc
                                                                           01827500
     CALL VECCUTIOFC(1.L) .FTEN. XAN( M.L))
                                                                           C1627600
     IF (LEGU) PHINT 236. M.L.L.KNI.N.AN.XAN(M.L)
                                                                           01627700
  & CENTINUE
                                                                           C1627800
 41 CONTINUE
                                                                           C1 #2 7900
                                                                           (1454000
     THAT'S IT FUN XMN IF KANE . 1
                                                                           (1828100
    IF (K.N. . 1) 00 10 8
                                                                           (1828200
     XMN( M.M ) = AMAS(N)
                                                                          C182830C
     IFILE JU) PRINT 237, M.N.N.XMN(M.A)
                                                                          C1628400
    CET TERMS ASSOCIATED WITH THE TRANSLATION I GUALLON
                                                                           C1 82 8500
     CALL SCLV(XMAS(N).FLAC(1.MN).TEM3)
                                                                           C1828600
    TE (PCCN (NBI) . EQ. J) GU TO B
                                                                           01628700
    NI = SUF (NOI)
                                                                           C1828800
     ME = SUF (NB1) + 2 - PCCN (NB1)
                                                                           01828900
     50 13 L=N1.N2
                                                                           01829000
     CALL VECENTIOFC(1.L) . TEME. X4N(M.E))
                                                                           (1829100
     (FILFOU) PRINT 215. M.L.L.N.MN.XMN(M.L)
                                                                           01658500
 1 - CONTINUE
                                                                           01829300
   + CONTINUE
                                                                           C1829400
                                                                           01629500
   IN CENSENTHATE EN EMT ARRAY NOW
                                                                          01 82 96 00
     PLT IN FILM . UFC ( DLT) TEAMS
                                                                           C16297CC
    TALL VELEUTIFIEM. CEMC(1.K).A)
                                                                           C1 F29800
    TN(N) - ETM(M) - A
                                                                          C1 E2 9900
    IF (LEGU) PRINT 2JE. M.N. KMI. N. MN. K. ETM(M)
                                                                          (1630000
     THAT 'S IT IF K.NE . 1
                                                                          CLABOLCO
    IF (K.N. . 1) GU TU 3
                                                                           C1630200
                                                                          C1 F 3 O 3 O O
    FUT IN SEKING-DASHECT EFFECT, MUCL AN
                                                                          01830400
    ETM(N) = ETH(M) - XMAS(N)*(Z.*ZLTA(NN)**LUM(MN)*THAD(M)
                                                                          C1830500
                                 + FLUM(MN) ** 2 * THA(M) )
                                                                           (1630600
    IF (LEGU) PRINT 239. N.N.N.NN.NN.NN.NN.M.ETM(M)
                                                                          C1E30700
    CALL VLLYUV(FLMC(1.N).FLFC.FC(L(1.N).A)
                                                                           C1E30800
    CALL VECEUT( TEM2. FLAC(1.MA) . H)
                                                                          C16309C0
    ETN( + ) = ETM (M) + A - F
                                                                           01631000
    IF (LEQU) PRINT 245. W. N. N. N. N. H. MN. LTM (M)
                                                                          C1631100
   - CUNTINUE
                                                                          01631200
                                                                          C1631300
                                                                          C1831400
    CHECK TO SEL IF CCUPLING SIGNIFICANT
                                                                          C1631500
    IF (NST4.EG.D) GL TC 11
                                                                          C1631600
    Kc a C
                                                                          C1 E31 700
     MN = 3
                                                                          01631800
    CC 35 K=1.NdOC
                                                                          C1E31900
    CHECK TO SEL IF BODY & FLEXIBLE
                                                                          C1E32000
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IF (SFXM(K).EU.O) GC TO 35
                                                                            C1E32100
      CYCLE THROUGH ALL GENERALIZED COURDINATE EQUATIONS FOR BODY K
                                                                            C1832200
C
                                                                            C1E32300
      AM = MM
      SFAMA = SFAM(K)
                                                                            C1E324C0
                                                                            C1832500
      CO 33 N=1.5F XMN
      MN = MN+1
                                                                            01832600
      (ALL INPACISTI .NSTI .SCXC(PN))
                                                                            C1 E32700
                                                                            C1632800
      IF (NST1 . EQ . 0) GO TO 33
       IF (LEGU) PRINT 25E. N.K. MN. (STI(1).I=1.NSTI)
                                                                            C1632900
      NI = NFER+MN
                                                                            C1E3300C
      CC 37 1=1.3
                                                                            C183310C
      KCUP(1.MA) = 0.0
                                                                            C1E33200
      CO 37 J=1.3
                                                                            C16333CO
                                                                            C1E33400
   37 FCUP(1.J.MN) = 0.0
       IF (LEGU) PRINT 245
                                                                            C1 £ 3 3 5 0 0
      IF (LEGU) PRINT 242. MN.MN
                                                                            C1E33600
      CO 34 1=1.NST1
                                                                            C1E337CC
                                                                            C1 633800
      * = STI(ASTI+1-1)
                                                                            C1633900
      NJ = MMN + M + NFER
      KF = KF+1
                                                                            C1634000
      (ALL SCLD(THA(MJ).FCF(1.1.KF).TMF)
                                                                            C1E341C0
      (ALL DYACD(FCUP(1.1.MN). TMF.FCJP(1.1.MN))
                                                                            C1134200
      IF(.NOT.LEGU) GO TO 5004
                                                                            C1 £ 34 300
      FRINT 245
                                                                            C183440C
                                                                            C1834500
      FRINT 24c.
                              (FCUP(1.L.MN).L=1.3)
      FRINT 247. MN.MN. MJ. KF. (FCUF(2.L. MN).L=1.3)
                                                                            C1#346C0
      FRINT 246.
                              (FCUP(3.L.MN).L=1.3)
                                                                            C183470C
 5004 (ALL SCLV(THAD(MJ).FCK(1.KF).TMK)
                                                                            C1 E3480C
      (ALL VECADD(KCUP(1.MN) .THK . KCUP(1.MN))
                                                                            C1E34900
      IF (.NCT.LEQUI) GO TO 5005
                                                                            C1 £350C0
      FRINT 245
                                                                            C1E35120
      FRINT 24E. MN.MN.NJ.KF. (KCUF(L.MN).L=1.3)
                                                                            C1635200
 SOCE CONTINUE
                                                                            C1E35300
   34 CONTINUE
                                                                            (1835400
      TRANSFURN FOUR AND KOUP TO COMPUTING FRAME
                                                                            C1 £35500
      (ALL TENTRN(FCUP(1.1.MN).XMC(1.1.K).FCUP1)
                                                                           C1 £35600
      (ALL VECTEN(KCUP(1.MN).XMC(1.1.K).KCUP1)
                                                                            C1 #35700
      IF (. NUT . LEQU) GO TC 5003
                                                                            C1635800
                                                                            C1835900
      FRINT 245
      FRINT 254.
                         (FCUP1(1.L).L=1.3)
                                                                            C1+36000
                                                                            C1836100
      FRINT 257. K.MN.K.(FCUP1(2.L).L=1.3)
      FRINT 254.
                        (FCUP1 (3.L).L=1.3)
                                                                            C1836200
                                                                            C1+36300
      EHINT 245
                                                                            C1836400
      PRINT ZEE. K.MN. (KCUPI(L).L=1.3)
                                                                            C1836500
 5003 CONTINUE
                                                                            C1836600
C
      CALL VUCYUV(FUNC(1.K).FCUP1.FCMC(1.K).A)
                                                                            C1 836700
      CALL VECCUT(FCMC(1.K).KCLP1.0)
                                                                            C183680C
      E+0.4 - A + (1M)MT3 = (14)4T3
                                                                            C1636900
                                                                            C1637000
      IF ( . NUT . LEUU) GU TC 53C7
                                                                            C1837100
      FRINT 245
                                                                            C1837200
      FRINT 245.MI.MI.K.K.K.ETM(MI)
                                                                            C1E37300
 5007 CONTINUE
   33 CONTINUE
                                                                            C1E37400
                                                                            C1 E37500
   35 CONTINUE
                                                                            C1637600
   11 CONTINUE
                                                                            C1637700
      THAT'S IT FUR MODAL COUPLING
C
                                                                            C1637800
C
                                                                            C1837900
C
                                                                            C1638000
C
      COMPLIATION FOR VARIABLE SPEED MCMENTUM WHEELS
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C
       EXPAND CIMENSIUM OF MATRIX EQUATIONS AND COMPUTE SCALAR ELEMENTS (1836100
       ASSCCIATED WITH PRESENCE OF MOMENTUM WHEELS
                                                                              C1638200
C
      (ALL UNPACISTI . NSTI . SMV)
                                                                              C183830C
                                                                              C1 #38400
      IF (NST1.E0.0) GO TC 5057
      IF (LEJU) FRINT 201. (STI(1). I=1. NSTI)
                                                                              C1838500
      CO 2 MANN=1.NST1
                                                                              C16386C0
                                                                              C1636700
      AND=ASTI-(MMMM-1)
      MM = STI(MMM)
                                                                              C1838800
                                                                              C1 E38900
      W = NFERINSTILL-MANHAMEDS
      XMA(A.M) = PLM(MM)
                                                                              C1639C00
      IF (LEQU)PRINT 203. M.M.M.XMN(A.M)
                                                                              C1839100
      (ALL UNPACISTE .NST2 . SCK( C( NW) ))
                                                                              C1E39200
      ETM(N) = 0.DC
                                                                              C1E39300
      IF (LEGU)FRINT 204. M.ETM(M)
                                                                              (1839400
      IF (NST2.EQ.0) GO TC 5058
                                                                              C1 839500
      CO 1 11=1.NST2
                                                                              20405812
      1 = 572(11)
                                                                              C1E39700
      CALL VECCOT(HMC(1.MM).DCFC(1.1).A)
                                                                              C1 F 3980C
      ETH(N) = ETH(M) - APPLM(NN)
                                                                              C1 #39900
      IF (LEGU)FRINT 207. M.M.M.M.IN.I
                                                                              (1840000
      KTER#=SGF(1)+2-PCCN(1)
                                                                              0104910
      KBEG=SJF(I)
                                                                              C164C200
      IF (KEEG.GT.KTERM) GO TC 48
                                                                              C1E40300
      CO 47 K=KBEG.KTERN
                                                                              C1840400
      N = K
                                                                              C1640500
      CALL VECCUT(HMC(1.MM).GFC(1.K).A)
                                                                              C1 640600
                                                                              C1840700
      XMN(N,N) = A +PLM(NN)
      IF (LEGUIPHINT 209. M.N. P. P. P. K. XMN (M.N)
                                                                              C1640800
   47 CCATINUE
                                                                              C1 E409CC
   4E CONTINUE
                                                                              C1641000
    1 CONTINUE
                                                                              C18411CC
                                                                              C1841200
 SOSE CONTINUE
      ETM(N) = ETM(M) + CLM(MM)
                                                                              C1641300
      IF (LEUJ) PRINT 210. M.M.MA.ETM(M)
                                                                              C1641400
                                                                              C1E41500
    2 CONTINUE
 5057 CONTINUE
                                                                              C1641600
C
                                                                              C1841700
C
                                                                              C1 E4 1800
C
                                                                              C1841900
      FILL IN UPPER TRIANGULAR PERTION
                                                                              C1642000
C
      NEWV = NEER+ NMJDS+NMV
                                                                              C1842100
      CC 9 M=1.NFMV
                                                                              C1E42200
      CO 9 N=N.NFMV
                                                                              C1642300
                                                                              01842400
    S XMA(P.N) = XMN(N.N)
      IF (. NCT. LEGUI GO TO 5706
                                                                              C1642500
      FRIN1 227
                                                                              01642600
       11 = NFNV/4
                                                                              C1 6427CO
      12 = NFMV - 4#11
                                                                              C1842800
      13 = 11 + 1
                                                                              C1842900
                                                                              C1 E4 3000
      CO 2C 1=1.13
                                                                              C1643100
      14 = 3
      IF (1.NE.13) GO TO 22
                                                                              C1643200
      1F(12.66.0) GO TO 20
                                                                              C1 E4 3 300
                                                                              C1843400
      14 = 12 - 1
                                                                          C1.843500
   22 15 = 4*(1-1) + 1
      CO 23 N=1.NFMV
                                                                              C1643600
      15F14 = 15 + 14
                                                                              C1643700
                                                                              C1 64 38CO
      PRINT 200. (IH.M.N.XMN(F.N).N=15.15P14)
                                                                              C1 84 3900
   23 CONTINUE
      FRINT ZZE
                                                                              C1644000
```

```
20 CONTINUE
                                                                           C164410C
     EG IN1 227
                                                                           C1844200
C
                                                                           (1844300
    COMPLIE (NOI)X1 COLUMN MATRIX OF VECTORS RESULTING FROM DIFFERT LATC1844400
      VECTORS MOVING RELATIVE TO FRAME OF COMPUTATION
C
     CONE SY EQUIVALENCE (DCMC. TEM)
                                                                           C1844600
C
     FRINT 202. (K.K. (TEM(1.K). [=1.3).K=1.Nd1)
                                                                           C1844700
     PRINT 227
                                                                           C18448C0
C
                                                                           CIFAAGOC
      MULTIPLY (NEL)X(NEL) INERTIA MATRIX XUIC #1TH (NEL)XI MATRIX TEM 01F45000
C
       NOTE THAT XCIC STOREC IN TRIANGULAR FORM PUT RESULT IN TEM
                                                                           C184510C
 SCCE CONTINUE
 2016 CONTINUE
                                                                           C1845300
      CO 24 K=1.Nb1
                                                                           11845400
      CC 25 1=1.3
                                                                           (1645500
   25 xQC(1.K) = 0
                                                                           C1 645690
      IF (LEGUIFKINT 215. K
                                                                           C1845700
      IF (K . NE . NB 1) GO TC 30
                                                                           C184580C
      CALL UNPACISTINSTINSTI
                                                                           C1645900
      6512 a C
                                                                           C1846000
      CC TC 31
                                                                           (1846100
   30 CALL CYPAC(STI.NSTI.SI(K))
                                                                           C184620C
      CALL UNPACISTZ.NSTZ.SK(K-1))
                                                                           C164c3C0
      164 = (1154)5TE
                                                                           C184640C
   31 CONTINUE
                                                                           C16465C0
                                                                           C1646600
      START MATRIX MULTIPLICATION RUN K TO RIGHT OF DIAGONAL
                                                                           C1E46700
C
                                                                           01640800
      IF (LEGU) FRINT 217.K. (ST2(1).1=1.NST2)
      IF (NST2.EQ.O) GO TO SCES
                                                                           C1646900
      CO 26 11=1.NST2
                                                                          C1647000
     ELEMENT KET CELETE IT WAS TAKEN CARE JF ABOVE
                                                                           C1647100
C
                                                                           C18472CC
                                                                           C1647300
     CHECK FLF MULTIPLICATION BY ZERJ
     HECALL FROM HATE THAT CONCINUIT = TEMICHOLD = 0
                                                                           C1847400
0
                                                                           C1 64 7500
      IF (I.Ed. Nol) GC TC 26
      IF ( . NUT . HULU(11) GC TO 2e
                                                                           C1 647600
      KI = KTI(Nol .K .I)
                                                                           C1E47720
                                                                           C1847800
      IF (LEGU) FRINT 223. K.K.KI.I.K.K.I.I
      NOTE THAT I . K TENSOR IS THE THANSPOSE OF THE K.I TENSOR
                                                                           C1 #4 79CO
        THIS FOREVER DOES NOT INSURE THAT INK IS SYMMETRIC. IN FACT
                                                                          CIEAHODO
         IN GENERAL IT WILL NOT BE SU HENCE DYTOV IS USED
                                                                           C1848100
      CALL DYTCV (XCIC(1.1.KI).TEM(1.1).TEAL)
                                                                           C1 F4 H200
     CALL VECADD(XQD(1.K).TEM1.XQD(1.K))
                                                                           CLEARSOO
  26 CONTINUE
                                                                           C1848400
 5055 CCATINUE
                                                                           C1846500
      IFILEGUIPHINT 228
                                                                           C1 8486CC
      IF (NSTI .EQ.O)GG TC 576C
                                                                           C1848700
      IF (LEJU)PRINT 216. K. (STI([]).[=1.NoT1)
                                                                           CIEABBCO
     CO 25 11=1.NST1
                                                                           C1848400
      1 = 511(11)
                                                                           CLEAGOOC
     IF ( . NGT . RBLO(11)) GC TO 25
                                                                           C1849100
      BCDY I FIGIC BODY
                                                                           C1649200
     KI = KTI(NB1.K.I)
                                                                           C1 E493CO
      IF (LEGU) FRINT 21d. K.K.KI.I.K.K.I.I
                                                                           C16494C0
      CALL DYGCTV(XCIC(1.1.KI).TEM(1.1).TEMI)
                                                                           C1 F49500
     CALL VECADD(XQD(I.K).TEM1.XGD(I.K))
                                                                           C1849600
  25 CONTINUE
                                                                           C1849700
SOCC CONTINUE
                                                                           C1849800
      IF (LEGUIPHINT 228
                                                                           C18499C0
     FINISHED MATRIX MULTIPLICATION RUN K UVER TO DIAGONAL
                                                                           C1850000
```

```
0
                                                                                    C1650100
      ACC LIF GYROSCEPIC & XOD AND EXTERNAL TURBUE ON NEST K-1
                                                                                    C1 65020C
                                                                                    (1650300
      IF (LEGU)FRINT 224, K, (ET((1.K). 1=1.3)
      IF (LEQUIPRINT 230. K. (XQL(1.K).1=1.3)
                                                                                    C1650400
      IF (LEGUIFFINT 231 . K. (PHI(1.K) . I=1.3)
                                                                                    C1650500
      CC 27 1=1.3
                                                                                    C1850600
                                                                                    C1 £50700
   . 7 ETC( Lin) = ETC( Lik) - XGE( Lik) + PHI( Lik)
       IF (LEUU IFRINT 231. K.K.K.K. (ETC(I.K). [=1.3)
                                                                                    C1 650800
   24 LENTINUE
                                                                                    C1650900
                                                                                    C1651000
      IF (. N. I. LEUL) GU TO 3000
      FRINT 227
                                                                                    C1651100
      CC 15 *-1:NH1
                                                                                    01851200
   15 FRINT 225, K. (ETC(1.K).[=1.3)
                                                                                    C1851300
      FRINT 227
                                                                                    C1651400
 1310 CONTINUE
                                                                                    C1851500
                                                                                    C1851600
       COMPLETE (NEWE) AT COLUMN MATRIX OF TURQUE COMPONENTS ALONG
                                                                                    C1851700
       FREE COUNDINATE AXES
                                                                                    C1651800
      EG 28 K=1.NH1
                                                                                    C1851900
                                                                                    C1652000
      MBEG = . JE (K)
      * TERRENETU+ = PEJNIKI
                                                                                    C1652100
      IF (MEED . UT . M TEHM) GO TO 5061
                                                                                    C1852200
      CO SE MENDEG.NTERM
                                                                                    C1452300
      CALL VECLOT ( UFC( 1.M) .ETC(1.K) . CTM(M))
                                                                                    C1652400
      IF (LEGUIFNINT 224. M.N.K
                                                                                    C1 652500
 EDEL CLATINGE
                                                                                    C1852600
   . - CUNTIALL
                                                                                    C1 £52700
      IF ( . NUT . LEUL) FETLEN
                                                                                    C1652800
      HEINT CET
                                                                                    C1852900
      MTENA = NEL KANNY NOCOS
                                                                                    01853000
      CO IC 4=1.MIERM
                                                                                    C1653100
   IL FRINT . co. M.ETM(A)
                                                                                    C1653200
                                                                                    C1653300
      SECUCITED OF VECTER CYACIC EGUATIONS TO SCALAR EQUATIONS COMPLETE CLESSACO
                                                                                    C1853500
                             SUM CLER N=1 . NFER+NMV+NMCDS
                                                                                    C165360C
                                                                                    C1653700
                      AMN(N.N) *THACO(N) = ETM(M)
                                                                                    C1853800
                                                                                    01853900
  200 FURMAT (4(2x.A4.12.'.'.12.') ='.015.8))
                                                                                    (1854000
  201 FORMAT (7/, LABELS OF VARIABLE SPEED MOMENTUM BREELS ',1015./) C185410C
  202 FORMAT 1' BODY '. 12. ' TIED TO SYSTEM AT RIGID HINGE ')
                                                                                    C1 E54200
  203 FORMAT(/;' XMN('.12.'.'.12.') = PLM('.12.') = '.D17.8)
                                                                                    C1854300
  204 -OFMAT (COA. ' ETM(".12.") = ".U17.8)
                                                                                    C1654400
  135 FORMAT ( ' NON-ZENC COLUMNS IN NOW ".12." OF ADIC OVER TO CLAGENAL C1854500
     WELLEMENT APE ".1115)
                                                                                    C1 85460C
  206 FCRMAT ( ' XMN( '.12, ', ',12, ') = UFC( '.12, '). (XDIC( '.12. ').QFC( '.12. (1654700
     *')) = afc(',12,').(x01((',12,',',12,').afc(',12,') = *.D17.8)
                                                                                    C1 E54800
  207 FORMAT (60x, ' ETM('.12.') = ETM('.12.') - PLM('.12.') * HMC('.12.C1654900
     **) . CCMC('.12.") ')
                                                                                    21 655000
  21E FORMAT (' TEM(', 12.') = DUMC(', 12.') = ',3D17.8) C1655100
205 FORMAT (' XMN(', 12.',', 12.') = PLM(', 12.') + HMC(', 12.') + GFC(', C1855200
                                                                                    C1855300
     *12.1) = '.017.8)
  21C FORMAT (£0X.' ETM('.I2.') = ETM('.I2.') + CLM('.I2.') = '.C17.E) C1855400
211 FORMAT (20X.' CAGC('.I2.') = XMC('.I2.')+CAG('.I2.') +) C185500
212 FORMAT (20X.' TEM2 = FLMC('.I2.') X (FCMC('.I2.') X CAGC('.I2.')*C1855600
                                                                                    C1655700
     9.3
  213 FORMAT (20x. ' TEN2 = TEN2 + FJMC('. 12.') X (FCMC('. 12.') X CEC('. (1655800
     912. 1 1 1)
                                                                                    C1 £55900
  214 FORMAT ( * AMN = 0.0 1.///)
                                                                                    C1 656000
```

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215 FORMAT (' x0G('.12.") = 0 ")
                                                                       01856100
216 FORMAT ( * RUW *.12.* OF XCIC LEFT OF CLASONAL USE ELEMENTS IN COLUCI856207
   * NNS 1.1315)
217 FORMAT ( HUM ".12." OF DDIC RIGHT OF DIAGUNAL SE LLEMENTS IN COLC1856400
   *LMAS '.1015)
216 FORMAT (' XUD(',12,') = XCC(',12,') + XC1C(',,,') . TEM(',12,')
                                                                       (1856600
   • =',' xGD(',12,') + xC1C(',12,',',12,') . *(',12,') ')
                                                                       C1856700
215 FORMAT (' XMN(',12,',',12,') = UFC(',12,') . (XMA5(',12,')*FLAC('C18568CC
   ·. 12.1) = '. 012.5)
22C FORMAT ( * XQD( *,12.*) = XGD( *,12.*) + XDL( *,12.*) ** T . TEM( *,12.*C1857000
   *) = >00('.12.') + XD1C('.12.'.'.12.') . TEM('.12.') ')
                                                                       21657122
222 FCRMAT (30x,' TEN2 = XMAS(',[2,')*TE42 =',17x,3012.5)
                                                                       C1857200
223 FORMAT (' ETM('.12.') = ".3C17.3)
                                                                       C1 £57300
224 FORMAT (' ETM('.12.') = GFC('.12.').LTC('.12.') ')
                                                                       C1857400
226 FORMAT ('1 SUBROLTINE OFCUT ENTERED 1.2(/))
                                                                       C1657500
227 FURMAT (3(/))
                                                                       C185760C
226 FORMAT ( . .)
                                                                       C16577C0
225 FCRMAT (' ETC('.12.") = '.3017.3)
                                                                       C1657800
230 FORMAT ( .
              xu0('.12.') = '.3017.d)
                                                                       C1857900
231 FORMAT (' PHI('.12.') = '.3017.8)
232 FORMAT (' CTC('.12,') = ETC('.12,') - XUD('.12,') + PHI(',12,') = (1650100
   * '.3017.E .//)
                                                                       C1858200
233 FORMAT (' ETM('.12.') = '.017.8)
                                                                       C1658300
234 FCFMAT (///.40x." BUDY ".12." IS A FLEXIBLE BUDY IN NEST ".12./) C185840C
235 FORMAT (/, ' FIEM(',12,',',12,',',12,') = XMAS(',12,') CAM(',12,',(165850C
   * '.12.') x FLAC('.12.') + FLQC('.12.') = '.3D12.5)
236 FOFMAT (' XMN(',12.',',12.') = UFC(',12.').FTEM(',12.',',12.',',12.',',12.688700
   . 2. 1) = 1 . (x . D 12 . 5)
                                                                       01858800
237 FORMAT (' XMN(', 12,',', 12,') = ', 23x, 012,5)
23E FORMAT (7.30x,' ETM('.12.') = ETM('.12.') - FTEM('.12.'.'.12.'.'.C1859000
   *12.11.0CNC(1.12.1) =1.3ex.012.0)
239 FORMA1 (3CX, ' ETM(',12,') = ETM(',12,') - XMA>(',12,')*(2.*2ETA('(1859200
   *.[2,*)*FLUM(*,[2,*)*THAC(*,[2,*) + FLJM(*,[2,*)**2*THA(*,[2,*) =*,(1659300
   .012.51
24C FURMAT (30X, ' ETM(',12,') = STM(',12,') + FLMC(',12,').FLHC(',12,C1859500
   4').F(MC('.12,') - TEMZ.FLAC('.12,') ='.19x.612.5)
                                                                       C1659600
241 FORMAT (33x. ' TEN2 = C ')
242 FORMAT (:0x. + FCLP('.12.') = 3
                                          KCUP('.12.') = 0')
                                                                       C1659800
245 FORMAT ( ' ')
                                                                       C1859400
246 FORMAT (EDX. 3012.5)
                                                                       (1860000
247 FURMAT (10x, ' FCUP(',12,') = FCUP(',12,') + THA(',12,')*FCF(',12,'C1860100
   •) = 1 .3012.5)
248 FORMAT (10x, ' KCUF(',12,') = KCUP(',12,') + THAD(',12,')*FCK(',12,C1860300
   ·*) = '. JO12.5)
245 FORMAT (JOX. ' ETM('.12.') = CT4('.12.') + FCMC('.12.').FCUP1.FCMC((1660500
   250 FURMAT (71x.3012.5)
                                                                       C16607C0
251 FORMAT (//.45x. MCDAL CHOSS COUPLING SIGNIFICANT FOR BODY 1.12)
                                                                       02806312
252 FCFMAT (/.30x.' ETM('.12.') = 0 ')
                                                                       0000310
            (30x, FLHC(',12,') = AMC(',12,')*FLH(',12,')*XMC(',12,'C1861000
253 FORMAT
   * 1 * * T = 1 . 3D 12 . 5 )
                                                                       C1861100
254 FORMAT (48x. 3012.5)
                                                                       C1861200
255 FORMAT (10x. * KCUP1 = XMC(*,[2,*) = KCUP(*,[2,*) = *,3012.5)
                                                                       C1E61300
256 FORMAT (/, * EQUATION OF MOTION FOR MODE *.12.* OF BUDY *.12.* ( DOCC1661400
   .E NUMBER '.12.') HAS CRESS COUPLING FROM MODES '.1014)
                                                                       C1861500
257 FORMAT (10x, * FCUP1 = XMC(*,12,*)*FCUP(*,12,*)*XMC(*,12,*)**T = *, $1661600
   • 30 12 .51
                                                                       C1861700
                                                                       01861800
                                                                       C1661900
    RETURN
                                                                       C1862000
```

C

```
C
                                                                           C1520000
      SUERCUTINE DCT
                                                                           (1522100
       USED TO DEFINE DIFFERENTIAL EQUATIONS WHICH MUST BE INTEGRATED
C
                                                                           C1900200
C
        TO DEFINE DIRECTION COSINE MATRICES
                                                                           C1520300
C
                                                                           C190040C
           50 = ALL CONTIGUOUS FAIRS OF BOOLES (K.JCON(K)) HAVING
C
                                                                           (1500500
C
                 SIGNIFICANT RELATIVE MUTICA. DELETION OF K FRCM SC
                                                                           C1530600
C
                 IMPLIES TRANSFORMATION MATRIX OF BODY K TO JOUNGE)
                                                                           C1500700
C
                 IS CONSTANT IN TIME, OR DEFINED BY SMALL ANGLE ASSUMPTIGGISCOBOC
c
                 OR . EULER ANGLE TECHNIQUES
                                                                           (1500900
C
                                                                           (1901000
C
                                                                           C1521100
C
                                                                           C1991200
      IMPLICIT HEAL+8(A-F.U-Z.1)
                                                                           C1501300
      LOGICAL FG1 . FG2 . FG3 . FG4 . F35 . INERF . HOLD . LEQU . LINIT(1)
                                                                           C1501400
                      LAUNGE , LTANSI , LVDIV , LEGUIV , LTAN ,
LTANV , LRATE , LXDY , LETA , LTGAGU ,
LGFDDT , LDCT , LANGLE , LSETUP , LSIMG
      LCGICAL
                                                                           C1501500
                                                                           (1501600
                                                                           C1501700
C
                                                                           C1901800
                                                                           C15C1900
      INTEGER
                                                                           C1502000
                     . CT2 . CT3
     . ABCSK . CTI
                                      , CT4 , CT5
                                                      . FCON . PCON .
                                                                           C1502100
                                                       . SFH
                                     . SFKDUM. SFK
                                                               . SG
     . SCNELM. SCN
                    . SCHOUP. SCH
                                                                           C1902200
                                                               . SLK
     • 51
             . 516
                      . SIXDUM. SIX
                                      . SKDUM . SK
                                                                        . (1902300
                                                       . SL
                                                              . SOF
             . SMCDUN. SMC . SMV
     . SNA
                                       . SOK . SPIDUM. SPI
                                                                          (1902400
                                               . SVB . SVD . SVI
. TCRG . SMAL . SEU
     . SCL
             · SH
                     . SSCN . SSIX
                                      . SVA
                                                                           (1902500
                              . SXM
     . SVM
             · SVP
                      . SVQ
                                      · SXT
                                                                           01602600
                    . NFL XB . SFLX . SFXM . NMODS . SFCC . SCC
              . SCG
                                                                          C1902700
     . IINIT(1)
                     · IZINIT(I)
                                      . SD
                                                                           C1902800
C
                                                                           C1922900
                                                                           C1 903000
     FEAL +8
                                                                           C1503100
     . ANGE (23)
                     . CAF (3.10) . ETIC (3.10) . ETMC (3.17) . 01503207
     • FLO (3.20) . FLE
                              (3.3.20). FLH (3.3.20).
                                                                           C1903300
     . THACO (33)
                     . YMCD (3.2.11). RINIT (1)
                                                      . AZINIT(1)
                                                                           C19034C0
C
                                                                           (1923500
C
                                                                           C1903600
      COMMEN /LDEBUG/ LRINGE . LTRNSI . LVDIV . LEGUIV . LTRAN .
                                                                           (1503700
                                      . LXDY , LETA . LTORQU . . LANGLE . LSETUP . LSIMQ
                       LTHANV . LHATE . LXDY
                                                                           C1523802
                       LOFDUT . LDCT
                                                                           C19C3900
C
                                                                           C19040C0
C
                                                                           C1904100
     COMMEN /LUGIC/ FGI. FGZ. FGJ. FGA. FGD. INEFF. HOLU(10)
                                                                           C1904200
C
                                                                           C1504300
C
                                                                           C1 904400
      COMMEN /INTG/ ANDRK(200) .
                                                                           C1504500
                                      , CT3
     • CT1
                     . C12
                                                       . CT4
                                                                        . (1904600
     • CT5
                     . FCON (33)
                                      . JCCN
                                               (10)
                                                       . LCON
                                                                (22)
                                                                          C1504700
                                      . N400
     . MC
                     . NE1
                                                       . NCTC
             (10)
                                                                          C1504800
                                      . NFRC
     . NFER
                     . NFKC
                                                       . NLOH
                                                                          C1504900
                                      . MMCA
                                                       . ASVP
     . ...
                      . AFO
                                                                          (1905000
                     . FCON (11)
                                     . 50
                                                       . SFR
     . NEVE
                                                               (33)
                                                                          C1505100
                                     . SIG
     . 56
                             (55)
                     . 51
                                                       . SL
                                                                           (1905200
     . SLK
             (33)
                      . SMA
                              (12)
                                      . 3UK
                                             (11)
                                                       . SUF
                                                               (11)
                                                                        . (1505300
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. 54
                                                                      . (1505400
     . SCL
             (11)
                    . SHV
                                                      . Sach
                                                                         £1505500
     . S:1x
                     . SVA
                                     . SVd
                                             6221
                                                   . .ve (22)
     . SVI
                     . ...
                                     . SVF
                                                                        (1905600
                                                   . SMAL
                                                                      . (1505700
     . SXM (3.10) . SXT
                                     . TUEG (47)
                                                                        C1505800
                    . NTO
                                     . SC
                                             (3.1)
                                                    . 566
     . SEU
     . NFL 1d
                     . SFL X
                                     . SF AM
                                             (10)
                                                     . NHCDS
                                                                         C1505900
                     . 500 (10)
                                                                         11506000
     . SFCC
                                                                         (1506100
                                                                         C1506200
     CCHMCH /INTGZ/
                                                                         C1506300
                . SCN
     . SCNELA
                             161
                                     . SCHLUM
                                                     . SCR
                                                            (9)
                                                                         C1506400
                                                     . 513
                    . SFK
                                     . SIXOUM
     . SFKELM
                             (4)
                                                             (9)
                                                                        C1506500
                    . SK
                             (5)
                                     · SPIDUM
                                                     . 501
                                                            (9)
                                                                         C1506600
     . SKOLM
                   . SMC
     . SECCUM
                             6 43
                                                                         C1906700
                                                                         C1 90680C
C
                                                                         C1 936900
C
     CCOMEN /REAL/
                                                                         C1907000
             (3.10) . CAC (3.10) . CLM
                                            (10) . COMC (3.11) . C1907100
     . ..
                                                     . FCMC (3.11) .
            (2.11) · ETC (3.11)
(3.06) · F
(10) · PHI (2.11)
     . CCMC
                                     . ETM
                                             (33)
                                                                        C1507200
                                             (3.10) . HMC
                                     . 1494
     . GAM
                                                                        (1907300
                                                     . OF
                                     . PLM
                                                              (3.33) . (1507400
     . HMC.
                                             (10)
                                     . ULC
     9 QFC
             (2.33) . GL
                             (2.22)
                                             (3.22) , HEME (3.11) . C1507500
                                                                     . 01507600
                                             (33) . THAD (33)
     · T
                                       THA
                                             (J.J.00). XI
     . THAC. (13) . THA. (10)
                                     . XCIC
                                                              (3.3.10).
                                                            (3.3.10). 01907800
             (3.3.10). XMAS (10)
                                     . XMN
                                             (33.33) . XMT
     . x1C
             (23) . FLA
                             (2.20) . FLB
                                                            (3.20) . (1507500
     . TUG
                                            (3.20) . FLC
                                            (3,10) • XIO (3,3,10) • (1978000
(3,20) • FLOC (3,20) • (1978100
(3,3,40) • FCK (3,40) • (1908200
                             (3.3.20). CAU
     · FLD
             (3.3.20). FLJ
     • FLIRC (3.10) . FLCRC (3.10) . FLAC
                                     . FLF
     * FLC * (20)
                   . ZETA (20)
     . TIMEND
                                                                         C1908300
                                                                         01908400
                                                                         (1508500
€
     COMMEN THE ALZ!
                                                                         CISCHEOR
                            (2.10) . COCCUM(1.3) . CHC
                                                              (3.1C) . C15C870C
     • CEDLM (1.3) . CE
     . XPCCUM(1.1.4) . XPC (2.3.10). CUM(3)
                                                                         (1508800
                                                                         CISCHSCO
C
                                                                         C190900C
C
                                            . (XMN(1.1). ANCD(1))
                                                                         (1629100
     EGLIVALENCE (ETM(1), THACE(1))
                  (XMN(1.3).YFCC(1.1.1))
                                            . ( AMN [ ! . 6 ] . CNF ( 1. 1) ]
                                                                         (1509200
                                             . ( xMv(1.10) . ( 1MC(1.11) .
                  (xMN(1.8).FTIC(1.1))
                                                                        (1506300
                                            . (FLE (1.1.1). FLO(1.1.1)).
                  (FLB(1.1).FLQ(1.1))
                                                                        C1909400
                  (FLH(1.1.1).FLJ(1.1.1))
                                                                         £1609500
                                            .(CA(1.1).WINIT(1))
                  ( -I.LINIT(I))
                                                                        (1909600
                                            . (ANDER(I). !INIT(II) .
                  ((I)TIAISA.(I.I)MUGG))
                                                                       (1609700
                  (SCNOLF. 121KIT(1))
                                                                         C1509800
                                                                         C1609900
C
                                                                         (1510200
     INTECEN SETLICE
                                                                         0210100
     EQLIVALENCE (LDCT.LEQU)
                                                                         C151020C
                                                                         C1910300
                                                                         (1910400
                                                                         C1510500
                                                                         (1910600
      IF ( . ACT . LEUL) GO TO 1000
                                                                         C161070C
     PRINT ICC
                                                                         CISICROC
      -C = C
                                                                         (1510900
      41 = 1
                                                                         CISTIOCC
      12 = E
                                                                         C1511100
      33 º 3
 100C CCATINUE
                                                                         C151120C
                                                                         C19113CC
      h = (
```

```
IF (LEGU) PRINT 104. INERF
                                                                          (1511400
                                                                          C1511500
      CALL INPACISET.NSET.SU)
      IF (NEET . Eu. O) GO TO 5062
                                                                          C1511600
      IF (LEGU) PRINT 103, SO. (SET(1).1=1.NocT)
                                                                          C1511700
      IF (INERF.UR. SET(NSET) . NE.1) GO TO 2
                                                                          C1911800
      TRANS BLDY I TO BODY I COMPUTING FRAME NOT NEEDED
                                                                          (1511900
                                                                          C1912000
      MSET = NSET - 1
      ACCOUNT FOR INERTIAL TO EGDY 1 THANSFORMATION
                                                                          C1512100
      ANGLLAR VELUCITY INERTIAL TO BODY 1
                                                                          (1512200
-
            = - ANGULAR VELOCITY ECDY 1 TO INERTIAL
                                                                          C1512300
C
            = - FUMC(I.1). I=1.2.3
                                                                          C1512400
      A = N+1
                                                                          C1 $1 2500
     CO 4 1=1.2
                                                                          C1512600
      CET MINES SIGN IN EY REVERSEING VECTUR CRUSS PRODUCT
                                                                          C1512700
      CALL VECEOS (XMC(1.1.0).FOMC(1.1).YMCO(1.1.N))
                                                                          C1512800
      IF(LEGU) PRINT 106. I.N.I.JC. (YMCD(J.I.N).J=1.3)
                                                                          C1512900
    4 CONTINUE
                                                                          C1913000
      IFILEGLI PRINT 105
                                                                          C1513100
    2 IF (NEET. EG. 0) GO TO 50c2
                                                                          C1513200
                                                                          C1513300
      CO 3 KK-1. NOET
                                                                          C1513400
      N = N+1
      K = SET(KK)
                                                                          (1513500
     CC 6 I=1.2
                                                                          CI 51 3600
      CALL VECTUS (CCMC(1.K).XMC(1.1.K).YMCD(1.1.K))
                                                                          C1513700
      IF (LEGU) PRINT 107. I.M.M.1.K. (YMCD(J.1.N).J=1.3)
                                                                          C1513800
    CENTINUE
                                                                          C151390C
                                                                          (1514000
      IFILEGUI PHINT 135
    3 CUNTINUE
                                                                          C1514100
 EDEZ CONTINUE
                                                                          C1514200
                 SUPRCUTINE CCT ENTERED "1
                                                                          C1514300
 ICC FORMAT ( 1
  103 FORMAT ( ' 50 = '.Ze. ' SET ELEMENTS '.1015)
                                                                          C1914400
 104 FORMAT ( * INERF = '.L10)
                                                                          C1614500
 10e FORMAT (' YMCD('.12.'.'.12.') = XMC('.12.'.'.12.') X FCMC( 1) = 'C1914700
     .3C17.d)
                                                                          C1514800
  107 FORMAT (* YMCO(*.12.*,*.12.*) = CCMC(*.12.*) x xMC(*.12.*,*.12.*) C1514900
     . = '.3017.8)
                                                                          C1515000
      SE TUEN
                                                                          C1515100
                                                                          C1915200
      ENC
                                                                         C2C000C0
     SUPRCLTINE ANGLE
                                                                         (2000100
       USED TO SET UP DIFFERENTIAL EQUATIONS WHICH DEFINE
                                                                         C2C00200
       ANCULAR DISPLACEMENT ABOUT FREE COURDINATES
C
                                                                          C20003C0
C
     RECALL
                                                                          C2C00400
           SFR(1) = FREE COORDINATE AXES ABOUT WHICH ANGLE TO
C
                                                                         C2CC0500
C
                      GE CCMPLIED
                                                                         C2C00600
(
                                                                         C2C00700
(
                                                                          0000000
                                                                         C2C00900
•
      IMPLICIT REAL . B(A-+.0-2.1)
                                                                          00010000
     LOGICAL FGI. FG2. FG3. FG4. FG5. INERF. ABLO, LEGU. LINIT(1)
                                                                         02001100
                     LEGULY . LEATE . LXDY . LETA . LTORGU .
                                                                         C5001500
                                                                         C2C01300
                      LOFDOT . LOCT . LANGLE . LSETUP . LSIMG
                                                                         C2C0140C
```

C

C2C01500

```
C
                                                                          02001600
      INTEGER
                                                                          02001700
     * ANDRK . CT1 . CT2 . CT3 , CT4 . CT5 , FCCN . PCDN . C2C01800

* SCNCUM. SCN . SCRDUM. SCR . SFKDUM. SFK . SFR . SG . C2C01900

* SI . SIG . SIXDUM. SIX , SKDUM . SK . SL . SLK . C2CC200C
            SMCDUM, SMC , SMV , SOK , SPIDUM, SPI , SQF
     * SMA
            SR • SECN • SEIX • SVA • SVE • SVD • SVI • C2002200

• SVP • SVG • SXM • SXT • TGRG • SMAL • SEU • C2002300

• SCG • NFLXB • SFLX • SFXM • NMODS • SFCC • SCC • C2002400
     . SCI
     . SVM
     * SC
                     · IZINIT(1)
     . IINIT(1)
                                      . 50
                                                                           02002500
C
                                                                           02002600
C
                                                                           02002700
      HEAL .
                                                                          02002800
                    . CNF (3.10) . ETIC (3.10) . ETMC (3.10) . 02002900
     * ANGE (33)
     * FLQ (3.20) . FLE (3.3.20), FLH (3.3.20).

* THACD (33) . YMCD (3.2.11), RINIT (1) . RZINIT(1)
                                                                          02003000
                                                                          C2C03100
C
                                                                          02033200
C
                                                                          02003300
      CCMMCN /LDEBUG/ LRUNGE . LTRNS! . LVDIV . LEGJIV . LTRAN .
                                                                         02003400
                      LTRANV , LHATE , LXDY . LETA . LTORQU .
                                                                          C2C03500
                      LGFDOT , LDCT , LANGLE , LSETUP , LSIMO
                                                                          02003600
C
                                                                          C2C03700
C
                                                                          02003800
     COMMEN /LUGIC/ FG1. FG2. FG3. FG4. FG5. INEMF. RBLO(10)
                                                                          (2003930
C
                                                                          C2C04000
C
                                                                          02004100
     COMMEN /INTG/ ANDRK(200) .
                                                                          C2C042C0
                                     . CT3
. JCCN (10)
                     . CT2
                                                     . CT4
                                                                       . 02004300
     • CT1
                                                    . LCON (22)
                     . FCON (33)
                                                                    . 02004400
     • CT5
                     . NFKC
     . ..
                                                     NEUR
             (10)
                                      . NBCD
     . NFEH
                                                                       . 02074600
                                      . NERL
                     . ...
                                                                       . (2004700
     . ...
                                      . NMOA
                                                     . NSVP
                     PCON (11)
E1 (55)
EMA (10)
                                     . 50
                                                     • SFR (33)
     . NEVC
                                                                          028004800
                                      • $1G
                                                                       . (2004900
                                     • SIG • SL
• SUK (11) • SUF (11)
     . 56
           (23)
                     . SMA
                                                                       . (2005000
     . SLK
                                                      SSCN
                    . SMV
                                                                       . (2(05100
     * SGL (11)
                                      · SR
                                                      . SVD . C2C05200
. SVG (33) . C2C05300
. SMAL . C2C05400
     . SSIX
                     . SVA
                                      · SVd
                                      . SVP (22)
     · SVI
                     . SVM
     . SXM (2.10) . SXT
                                      . TUHU (47)
     ■ NFL>d
                     . NTO
                                      . SC (33)
                                                     . SCG
                                                                      . 02005500
                                                                      . (2005600
                     . SFLX
                                      . SFXM (10)
                                                     . NMCDS
                     · SCC
                            (10)
                                                                          C2CC57CO
C
                                                                          C2005800
C
                                                                          02005900
     CCMMCN /INTUZ/
                                                                          C2C06C00
               . SCN (5)
                                                    . SCH
     . SCNCLM
                                      . SCHOUM
                                                             (9)
                                                                          (2(06100
                                      · SIXDUM
                     . SFK (5)
                                                      . SIX (9)
    . SFKCLM
                                                                      . (2006200
     . SKOLM
                     . SK
                             (5)
                                      · SPICUM
                                                      . SPI (9)
                                                                       . 02006300
     · SMCCLM
                    . SMC
                             (5)
                                                                          C2C06400
C
                                                                          C2C06500
C
                                                                          02006600
     COMMEN /FEAL/
                                                                          (2006700
    (10) . CCMC (3.11) . C2C06800
(33) . FCMC (3.11) . C2C0690C
(3.10) . FMC (3.10) . C2C070C0
                                      . 11M
                                                     . GF
     • FMC # (10) . FFI (3.11) . PLM (10)
                                                              (3.33) . (2007100
     4 OFC (3,35) , GL (3,22) , QLC
                                              (3.22) . HEMC
                                                             (3.11) . (2007200
    THA
                                              (33)
                                                     . THAD
                                                              (33)
                                      . XDIC (3.3.66). XI
                                                              (3.3.10). 02007400
     4 XIC (2.3.10). XMAS (10) . XMN (33.33) . XMT (3.3.10). (2007500
```

```
(33) . FLA
     * TUG
                              (3,20) , FLB (3,20) , FLC
                                                              (3.20) . (2007600
     * FLD (3,3,20), FLJ (3,3,20), CAO (3,10) , XIU (3,3,10), C2C07700
* FLIFC (3,10) , FLCRC (3,10) , FLAC (3,20) , FLGC (3,20) , C2C07800
     . FLC.
                     . ZETA (20) . FCF
                                              (3.3.40). FCK
                                                                (3.40) .
                                                                            C2CC7900
             (20)
     . TIMEND
                                                                            C2C08000
C
                                                                            02180252
C
                                                                            C2CC8200
     CCHMEN /FEAL Z/
                                                                            0.008300
     * CEDLM (1.3) . CE
                              (3.10) , COCDUM(1.3) , COC
                                                                (3.10) .
                                                                           C2C084C0
     * XMCCLM(1.1.9) . XMC (3.3.13). CBN(3)
                                                                            C200850C
C
                                                                            02008600
C
                                                                            02008700
     EQLIVALENCE (ETM(1). THADE(1))
                                             . (XMN(1.1). ANGD(1))
                                                                           02008800
                   (XMN(1.3).YMCE(1.1.1))
                                              . (XMN(1.0).CNF(1.1))
                                                                            00680523
                   (XMN(1.8).ETIC(1.1))
                                              .(XMN(1.10).ETMC(1.1)) .
                                                                           0200000
                                              .(FLE(1.1.1).FLD(1.1.1)).
     .
                   (FLB(1.1).FLQ(1.1))
                                                                           02009100
                   (FLH(1.1.1),FLJ(1.1.1))
                                                                            02009200
                                              . (CA(1.1).KINIT(1))
     .
                   (Fil.LINIT(1))
                                                                            C2C09300
                                             .(AsuRK(1), IINIT(1))
                   (CODUM(1.1).FZINIT(1))
                                                                           C2C0940C
                   (SCNDLM. IZINIT(1))
                                                                            C2C09500
C
                                                                            02009600
      EGUIVALENCE (LANGLE.LEGU)
                                                                            C2C09700
      INTEGER $1(33).52(33)
                                                                            C2C298CC
C
                                                                            02009900
C
                                                                            C2C1C000
C
                                                                            02010100
C
                                                                            0.2010200
C
                                                                            02010300
      IF (LEQU) PRINT 100
                                                                            C2C12400
C
                                                                            C2C10500
C
      FRECEED SEQUENTIALLY NEW DEFINING UNLY THOSE EQUATIONS CALLED FOR (2010600
C
      TAKING SPECIAL NOTE OF 3-AXIS GIMBALS BETWEEN RIGIC BODIES
                                                                            (2010700
      IF (LEJU) PRINT 101. NFRC. (SFR(1). I=1. NFRL)
                                                                            C2C10800
      K = 1
                                                                            02010900
      w = 1
                                                                            (2(11000
      CC 5 N=1.Nd1
                                                                            02011100
      IF (N.E .. 1) GU TO 9
                                                                            C2011200
      # = #+J-FCUN(N-1)
                                                                            C2011300
    S CENTINUE
                                                                           02011400
      MT = FIGHEST MAGNITUDE INDICE AT HINGE PUINT N-1
                                                                            02011500
      MT = M+2-PCUN(N)
                                                                           02011600
    7 IF (SFR(K).GT.MT.JR.K.GT.NFRC) GU TO 5
                                                                           02011700
      IF (N.EG.NOI) GC TC 4
                                                                           02011800
      IF (RELO(N) . AND . PCCN(N) . EC. O) GJ TJ 6
                                                                           02011900
      IF (RELU(N) . AND . PCCN(N) . EG. 1) GU TO 1
                                                                           C2C12000
    4 CENTINUE
                                                                           02012100
      IF (SFR(K).EU.A) GC TO 5
                                                                           C2C12200
      ANCD(K) = THAD(SFF(K))
                                                                           C2012300
      IF (LEGU) KK=SFR(K)
                                                                           C2C12400
      IF (LEGU) PRINT 102. K. KK. ANGO(K)
                                                                            02012500
      K = K+1
                                                                           02012600
      CC TC 7
                                                                           02012700
                                                                           C2C128C0
      SPECIAL CASE CHECK FOR SKENED THU AXIS GINBAL
                                                                           C2C12900
    1 CALL VECCUT(QFC(1.M).QFC(1.M+1).C)
                                                                           C2C13000
      IF (C.EU.C.DO) GU TC 4
                                                                           C2C131CO
      CALL VECCOT(QFC(1.M).ACMC(1.N).A1)
                                                                           C2C13200
      (ALL VECCOT(QFL(1,M+1),FCMC(1,N),A3)
                                                                           02013300
      ANGD (K) = (A1 - C#A3)/(1.00 - C##2)
                                                                           C2C1 34CC
      ANGC (K+1) = (A3 - C*A1)/(1.00 - C**2)
                                                                           C2C13500
```

```
IF ( . NUT . LEQU) GO TC 10C1
                                                                              02013600
      N1 = M+1
                                                                              02013700
       K1 = K+1
                                                                              0.00E 10C
      FRINT 103. MINIAL
                                                                              02013900
      FRINT ICE. MI.N.A3
                                                                              22014000
      FRINT ICC. M.MI.C
                                                                               12014100
       FRINT 107. K.ANGD(K)
                                                                               02014200
      FRINT 1CS. KI.ANGC(KI)
                                                                              02014300
 1201 CONTINUE
                                                                              02014400
       K = K+2
                                                                              02014500
      GO TC 5
                                                                              12014600
C
                                                                              C2C14700
    E CENTINUE
                                                                              02014800
C
       SPECIAL CASE THREE AXIS CINEAL - NOTE LOGIC ASSUMES THAT
                                                                             Cc C14900
                                          SFR(K),SFR(K+1),SFR(K+2)
                                                                             02015000
C
C
                                          ARE THE THREE GIMBAL ANES
                                                                              02015100
      CALL VECCOT(GFC(1.M).RCMC(1.N).A1)
                                                                              12015200
      CALL VECLOT(UFC(1.M+1).FCMC(1.N).A2)
                                                                              02015300
      CALL VELOUT(OFC(1.N+2).FCMC(1.N).A3)
                                                                              02015400
      CALL VECEST(UFC(1.M).QFC(1.M+2).C)
                                                                              02015500
       ANCD(K) = (A1 - C*A3)/(1 - C**2)
                                                                              02015600
                                                                             1 02015700
       AN (D (K+1) = A2
       ANGD (K+2) = (A3 - C*A1)/(1 - C**2)
                                                                              02015800
      IF ( . NLT . LEUL) GC TC 1000
                                                                              02015900
      M1 = M+1
                                                                              02016300
      N2 = N+2
                                                                              02016100
      K1 = K+1
                                                                              02016200
      K2 = K+2
                                                                              02016300
      FRINT 103. M.N.AL
                                                                              C2C16400
      FRINT 104. MI.N.AZ
                                                                              02016500
      FRINT ICE. MZ.N.A3
                                                                              (2016600
      FRINT 106. M.M2.C
                                                                              02016700
      FRINT 107. K.ANGD(K)
                                                                              02016800
      FRINT ICE. KI.ANGC (K+1)
                                                                              02016900
      FRINT ICS. KZ.ANGD(K+2)
                                                                              02017000
 1000 CONTINUE
                                                                              02017100
      K = K+3
                                                                              02017200
   E CONTINUE
                                                                              02017300
                                                                              02017400
  ICC FORMAT ("1 SUBROLTINE ANGLE ENTERED ")
                                                                              02017500
  ICT FORMAT (110, ' ELEMENTS IN ARRAY SER, THEY ARE '.3313)
                                                                             02017600
  1C2 FURMAT (' ANGD(',12,') = THAD(',12,') = ',C17.8)
1C3 FURMAT (' A1 = OFC(',12,') . RUMC(',12,') = ',017.8)
1C4 FORMAT (' A2 = OFC(',12,') . RUMC(',12,') = ',017.8)
                                                                             02017700
                                                                              02017800
                                                                             52517900
  105 FURMAT (' A3 = OFC(',12,') . RUMC(',12,') = ',017.8)
                                                                             02018300
                  C = OFC('.12.') . JFC('.12.') = '.017.8)
  106 FURMAT ( '
                                                                             02018100
  107 FORMAT ( .
                  ANGU('.12.') = (A1-C*A3)/(1-C**2) = '.017.8)
                                                                              C2018200
                                                       = (,017.8)
  108 FORMAT ( .
                  ANGD( 1.12.1) = A2
                                                                              02618300
  109 FORMAT (' ANGD('.12.') = (A3-C*A1)/(1-C**2) = '.017.8)
                                                                             02018400
  110 FURNAT (110, ' ELEMENTS IN AFRAY SMA, THEY ARE ',1013)
                                                                             02018500
      SE TUEN
                                                                              02018600
                                                                              02018700
      ENC
                                                                             02100000
C
     SUPHCUTING SETUP(Y.YD.NEC.SCHT)
                                                                             02100100
        IF SCAT = .THUE. SCAT CUT INTEGRATED QUANTITIES
                                                                              00200150
```

```
= .FALSE. SET UF JNE DIMENSIONAL ARRAY OF EQUATIONS TOC2100300
5
                            BE INTEGRATED
                                                                         C2100400
C
                                                                         (2130500
0
                                                                         02100600
      IMPLICIT REAL*E(A-H.O-Z.1)
                                                                         C2100700
0
                                                                         02100800
C
                                                                         02130900
      LOGICAL FGI. FG2. FG3. FG4. F35. INERF. RBLD. LEUU. LINIT(1)
                                                                         02101000
                     LRINGE . LTRNSI . LVDIV . LEQUIV . LTRAN .
      LOCICAL
                                                                         (2101100
                                                                        02101200
                      LOFDOT . LOCT . LANGLE . LSETUP . LSIMO
                                                                        C2101300
C
                                                                         C2101400
                                                                         C2101500
      INTEGER
                                                                         02101600
     . ANDEK . CTI
                   . CT2 . CT3 . CT4 . CT5 . FCCN . PCCN . C2101700
     * SCNEUM. SCN
                    . SCRDUM. SCF
                                     . SFKDUN. SFK . SFR . SG
                                                                        CE 101800
     * 51
            . 516
                     . SIXDUM. SIX
                                     . SKDUM . SK
                                                     . SL
                                                             . SLK
                                                                         02101900
                                                             . SQF
             . SMCDUM. SMC . SMV
                                     . SUK . SPIDUM. SPI
                                                                        C2102000
                                     . SVA
     * SCL
            . SR
                    . SSCN . SEIX
                                             . SVE . SVD
                                                             . SVI
                                                                     . (5105100
                                     . SXT . TURG . SMAL . SEU . SFXM . NMOUS . SFCC . SCC
            . SVP
                    . SVQ . SXM
     * SVM
                                                                     . (2102200
                    . NFLXB . SFLX
     * SC
             . SCG
                                                                        02102300
                    . IZINIT(1)
     * IINIT(1)
                                      . SD
                                                                         02102400
C
                                                                         02102500
C
                                                                         02102600
      FEAL +8
                                                                         C2102700
     . ANGE (33)
                     . CAF
                            (3.10) . ETIC (3.10) . ETMC (3.10) .
                                                                        02102800
           (3.20) . FLE
                            (3.3.20), FLH (3.3.20).
     * FLQ
                                                                         02102900
     * THACD (33)
                    . YMCD (3.2.11), RINIT (1)
                                                    . FZINIT(1)
                                                                         02103000
C
                                                                        C2103100
0
                                                                         (2103200
      COMMEN /LDEBUG/ LAUNGE . LTRASI . LVDIV . LEGUIV . LTRAN .
                                                                        02103300
                     LTRANV . LRATE . LXDY . LETA . LTORQU .
                                                                        (2123400
                      LOFDOT , LDCT , LANGLE , LSETUP , LSIMU
                                                                        C2103500
                                                                         02123600
0
                                                                         C210370C
     COMMEN /LOGIC/ Ful. FG2. FG3. FG4. FG5. INERF. RBLU(10)
                                                                        C2103H0C
C
                                                                        02123900
                                                                         02104000
     COMMEN /INTG/ AWORK(184) .ST1.N.M.MM.NST1.J.1.
                                                                         02104100
                    . CT2
                                     . CT3
                                                     . CT4
     * CT1
                                                                      . (2174200
     # C15
                                                     . LCCN
                                                                      . 02124300
                     . FCCN (33)
                                     . JCEN (10)
                                                             (22)
     . MC
             (10)
                    . NE1
                                     . NOOD
                                                     . NCTC
                                                                        C2124400
     * NFER
                     . NFKC
                                     . NFRC
                                                     . NLUK
                                                                         02104500
                     . MMO
                                     . NMUA
     . NHV
                                                     . ASVP
                                                                        C2104600
                     . FCCN
     * NEVE
                                     . 50
                                                     . SFR
                            (11)
                                                             (33)
                                                                         C2104700
     * SG
                     . 51
                             (55)
                                     . 516
                                                     . SL
                                                                         C2104800
     * SLK
                    . SMA
                                     . Suk
           1:11
                             (10)
                                             (11)
                                                     . Suf
                                                             (11)
                                                                         C2104900
                    . SMV
     * SGL
           (11)
                                     . SR
                                                     . SSCN
                                                                        (2105000
     . SSI>
                     . SVA
                                     . SVB
                                                     . SVD
                                                                        02105100
     * SVI
                     . SVM
                                     . SVP
                                             (22)
                                                     . SVG
                                                             (33)
                                                                        02105200
            (2.10)
     * SIM
                    . SXT
                                     . TURU (97)
                                                     . SMAL
                                                                         C2195300
                                     . SC
                                                     . SCG
     * SEU
                     . NTQ
                                             (33)
                                                                        C2105400
     * NFL Nd
                     . SFLX
                                     . SFXM (10)
                                                     . MMODS
                                                                      . 02105500
     * SECC
                     . 500
                             (10)
                                                                         C21056C0
C
                                                                         C2105700
                                                                         C2105800
     CCHMCH /INTGZ/
                                                                         02105900
     * SCNELM
                    . SCN
                             (6)
                                     . SCHOUM
                                                    . SCR
                                                            (9)
                                                                    . (2196000
                    . SFK
     . SEKEUM
                             (5)
                                     . SIXDUM
                                                     . SIX
                                                             (9)
                                                                        02126100
     . SKOLP
                    . SK
                             (5)
                                     . SPIDUM
                                                     . SPI
                                                             (9)
                                                                     . (2106200
```

```
. SMC (5)
     * SMCEUM
                                                                                C2106300
C
                                                                                C2106400
C
                                                                                (2106500
      CCHMIN /FEAL/
                                                                                C2126600
                                                 (10) . CCPC (3.11) . 02196700
             (2.10) . CAC
                              (3.10) . CLM
      * CA
     (33) , FLMC (3.11) , C2106800
(3.10) , HMC (3.1C) , C2106900
                                                (33)
                                                          . UF
                                                                   (3.33) . 02107000
                                                 (10)
      4 OFC (3.33) , CL (3.22) , OLC
                                                (3.22) , RUMC (3.11) , (21)7100
                                                (33) , THAD (33) , C2177200
(3,3,66), XI (3,3,1C), C2177300
(33,33) , XMT (3,3,1C), C2177400
                                        THA (33) , THAD (33) , ADIC (3,3,10
     * T
     * THACA (10) . THAW (10)
     * XIC (3.3.10), XMAS (10) , XMN (33.33), XMT (3.3.10), (2107400
* TLG (33) , FLA (3.20) , FLB (3.20) , FLC (3.20) , (2107500
     * FLD (3.3.20), FLJ (3.3.20), CAG (3.10) , X10 (3.3.10), C2107600

* FLIRC (3.10) , FLCRC (3.10) , FLAC (3.20) , FLGC (3.20) , C2107700

* FLCR (20) , ZETA (20) , FLF (3.3.40), FCK (3.40) , C2107800
      . TIMENO
                                                                               (2107900
C
                                                                               C2128C2C
C
                                                                                (2108100
      CENMEN / FEAL Z/
                                                                                (2108200
      * CEDLM (1.3) . CE
                              (3.10) , CHCDUM(1.3) , CHC (3.10) , C2108300
     * XMCCLM(1.1.9) . XMC (3.3.10). CBN(J)
                                                                                C2138400
C
                                                                                02108500
C
                                                                                (2128602
                                                 .(XMN(1.1).ANGD(1))
      EULIVALENCE (ETM(1). THADE(1))
                                                                               C2108700
                  (XMN(1.3).YMCC(1.1.1))
                                                .(XMN(1.6),CNF(1.1))
                                                                              02108800
                   (XMN(1.8).ETIC(1.1))
                                                                              (2128400
                                                 . (XMN(1.10).ETMC(1.1)) .
                   (FL8(1.1).FLG(1.1))
                                                 .(FLE(1.1.1).FLD(1.1.1)).
                                                                               02129000
     ٠
                   (FLH(1.1.1).FLJ(1.1.1))
                                                                               C210910C
                   (Ful.LINIT(1))
                                                 .(CA(1.1).RINIT(1))
                                                                               (2109200
                   (CEDUM(1.1).HZINIT(1))
                                                 . (AWURK(1), IINIT(1))
                                                                              02109300
                   (SCHOLK. IZINIT(1))
                                                                               C2109400
C
                                                                                02109500
      INTECER STILLO
                                                                                C2139630
      LOCICAL SURT
                                                                                C2109700
      CIMENSICH Y(NEU) . YO(NEC)
                                                                                C210980C
      EGUIVALENCE (LSETUF.LEGU)
                                                                                02109900
                                                                               02110000
C
                                                                               02110100
(
      IF (LEGU) PRINT 100
                                                                               02110200
C
                                                                               (2110300
      ANGULAR CH LINEAR HATE RELATIVE TO FREE COURDINATE AXES
                                                                               $211 0400
      CC 1 N=1.NFEH
                                                                               02110500
      IF (SCAT) GJ TO 10
                                                                               C211060C
      YD(N) = THALD(N)
                                                                               02110700
      IF (LEGU) PRINT 102. N.N.YC(N)
                                                                               20801123
                                                                               (2110900
      CO TC 1
   1: THAD (N) = Y(N)
                                                                               (511163)
      IF (LEGU) PRINT 202, N.N. THAC (N)
                                                                               02111100
    1 CONTINUE
                                                                               02111200
      NEG = NEEK
                                                                               (2111300
C
                                                                               (2111400
                                                                               02111500
C
      GENEFALIZED ELASTIC COURCINATE HATL EQUATIONS
                                                                               02111600
      IF (NHODS . EQ. 0) GJ TO 5063
                                                                               C2111700
      DO 7 NN=1.NMCDS
                                                                               C2111800
      N = NEGANN
                                                                               (2111900
      IF (SCRT) OU TO 9
                                                                               0201123
                                                                               C2112100
      YC (N) = THADC(N)
      IF (LEGU) PRINT 102. N.N. YD(N)
                                                                               021115500
```

```
CC TC 7
                                                                              (2112300
    S THAD(N) = Y(N)
                                                                              C2112400
      IF (LEGU) PRINT 202. N.N. THAC (N)
                                                                              C2112500
    7 CCATINUE
                                                                              C2112600
                                                                              C21127C0
 5063 CONTINUE
      NEC = NEG + NMUDS
                                                                              C2112800
                                                                              02112900
C
C
                                                                              02113000
C
      RELATIVE ANGULAR PLMENTLY WHEEL
                                                                              (2113100
      (ALL UNPAC(STI.NSTI.SMV)
                                                                              C2113200
      IF (NST1.EQ. 0) GO TC 5064
                                                                              C2113300
      CO 2 MMM=1.NST1
                                                                              C2113400
      AW=NST1-(MMM-1)
                                                                              C21135C0
      W = STI(MM)
                                                                              C2113690
      N = NEQ+NST1+1-MM
                                                                              C2113700
      IF (SCRT) GO TO 11
                                                                             C211380C
      YD (N) = THACD(N)
                                                                              02113900
      IF (LEGU) PRINT 104. N.A.YC(N)
                                                                              C21140C0
      CO TC 2
                                                                              02114100
   11 THAD .(M) = Y(N)
                                                                              C2114200
      HMCM(F) = PLM(M) = THADW(M)
                                                                              C2114300
      IF (LEQU) FRINT 205. M.N. THACK(M)
                                                                              (2114400
      IF (LEGU) PRINT 234. W.M.M.HNCM(M)
                                                                              (2114500
    2 CONTINUE
                                                                              02114600
 5064 CONTINUE
                                                                             C21147C0
      NEC = NEC + NST1
                                                                              (2114800
                                                                             C2114400
C
      DISPLACEMENT ABOUT OF ALCNG FREE COCRDINATE AXES
                                                                             C2115CCC
      IF (NFRC . EQ . 0 ) GO TC 5065
                                                                             C2115100
      CO 3 MP=1.NFRC
                                                                             C2115200
      N = NEQ + MM
                                                                             C2115300
      IF (SCRT) GG TO 12
                                                                              C21154CC
      YD (N) = ANGD (MM)
                                                                             C2115500
      IF (LEGU) PRINT 1C6. N. M. YO (N)
                                                                             C2115600
      GO TC 3
                                                                             (2115700
   12 N = SFR(MM)
                                                                             C2115800
      THA(N) = Y(N)
                                                                             C211590C
      IF (LEGU) PRINT 206. M.N.THA(M)
                                                                             C2116000
    3 CCATINUE
                                                                             02116100
 SOES CONTINUE
                                                                             C2116200
      NEG = NEG + NEGC
                                                                             C21163C0
C
                                                                             C21164C0
C
                                                                             (2116500
      GENERALIZED ELASTIC COORDINATE DISPLACEMENT EQUATIONS
C
                                                                             C2116600
      IF (NMCDS.EQ. C) GO TO SCE2
                                                                             C2116700
      CO 15 NA=1.NMODS
                                                                             C2116800
      A = MEO+AN
                                                                             C2116900
      ASTI = AFER+AN
                                                                             C2117000
      IF (SCRT) GU TO 20
                                                                             C2117100
      VC (N) = THAD (NST1)
                                                                             C2117200
      IF (LEGU) PRINT 103. N.NSTI. YOUN)
                                                                             02117300
      GO TC 19
                                                                             C21174C0
   2C CONTINUE
                                                                             C211750C
                                                                             C2117600
      THA(NST1) = Y(N)
      IF (LEGU) PRINT 206, NSTI .N. THA (NSTI)
                                                                             C2117700
                                                                             C2117800
   15 CONTINUE
SOEZ CONTINUE
                                                                             C2117900
      NEG = NEG + NMODS
                                                                             C211 8000
C
                                                                             C2118100
C
                                                                             C2118200
```

```
EISPLACEMENT ABOUT WHEEL SPIN AXIS
                                                                               (2118300
      IF (NMCA.EQ.O) GO TC 5066
                                                                               C2119400
      CO 4 MM=1 .NMOA
                                                                               C2118500
      . = SMA(MM)
                                                                               02118600
      N = NEQ + MM
                                                                               C21187CO
      IF (SCRT) GO TO 13
                                                                               C2118H00
      10(N) = THADW(M)
                                                                              C2118900
      IF (LEGU) PRINT 108. N.A. YC(h)
                                                                               C211900C
      CC TC 4
                                                                              (2119100
   13 CONTINUE
                                                                               02119200
                                                                              02119300
      THAW(N) = Y(N)
      IF (LEGU) PRINT 208. M.N. IFAL (M)
                                                                               C2119400
                                                                              C2119500
    A CONTINUE
                                                                              C2119600
 5066 CENTINUE
                                                                              C2 119700
      NEQ = NEG + NMUA
                                                                              C2119800
0
      CIRECTION CUSINES
                                                                              0.00000
      CALL UNPACISTI . NSTI . SD )
                                                                              C2120000
                                                                              (2120100
      A = NEG
                                                                              62120200
      A = C
      1F (NET1 . EQ . J ) GU TO 5067
                                                                              (2120300
      IF (INERF.OK.STI(NEILI.NE.I) GU TU 5
                                                                              02120400
      AST1 = NST1 - 1
                                                                              (2120500
      IF (SCAT) GU TU 14
                                                                              CS150600
                                                                              02120700
      A = 8+1
   14 CO 8 J=1.2
                                                                              C2120H0C
      CO 8 I=1.3
                                                                              02120900
                                                                              02121000
      N = N+1
                                                                              (2121100
      IF (SCHT) GU TO 15
      YD (N) = YMCD(I.J.M)
                                                                               CS121500
                                                                              C2121300
      IF (LEGU) PRINT 111. N.I...M. YD (N)
      CO TC 8
                                                                              C2121400
   15 XMC(1.J.F) = Y(N)
                                                                              C2121500
      IF (LEQU) PRINT 211. 1.J. N. N. XNC(1.J.M)
                                                                              02121600
                                                                              C2121700
    E CONTINUE
    5 IF (NET1.EU.D) 60 16 500/
                                                                              C2121800
      CO 6 MM=1.NST1
                                                                              02121900
      IF (SCAT) GO TO 16
                                                                              (2122000
      . . ...
                                                                              02122100
      60 TC 17
                                                                               (2122300
   16 # = ST1 (MM)
                                                                              02122300
   17 CO 6 J=1,2
                                                                              02122400
      CO 6 1=1.3
                                                                              C2122500
                                                                              02122600
      A = A+1
      IF (SCRT) GO TO 18
                                                                              C2122700
                                                                              02122800
      10(N) = YMCD(I.J.M)
                                                                              C2122900
      IF (LEGU) PRINT 111. N.I... P. YO(N)
      60 TC 6
                                                                              020233000
                                                                              C2123100
   16 XMC(1.J.M) = Y(N)
      IF (LEGU) PRINT 211. I.J.P.N.XMC(I.J.M)
                                                                              C2123200
    & CONTINUE
                                                                              (2123300
SOE? CONTINUE
                                                                              02123400
      MEC = N
                                                                              C2123500
      IF (LEGU) PRINT 112. NEG
                                                                              C2123600
 100 FORMAT ("I SUBROUTINE SETUP ENTERED ")
                                                                              (2123700
  102 FORMAT (' YO(',12,') = THACO(',12,') = ',D20.0)
                                                                              C2123800
 103 FORMAT (' YD(',12,') = 1HAC(',12,') = '.020.8)
202 FORMAT (' THAD(',12,') = Y(',12,') = '.020.8)
                                                                              (2123900
                                                                              C212400C
 104 FORMAT (' YD('.12.') = 1FADD('.12.') = '.020.8)
                                                                              C21241CO
 204 FORMAT ( ' HMOM('.12.') = FLM('.12.') * THACH('.12.') = '.020.8) (2124200
```

```
205 FORMAT (' THADW('.12.') = Y('.12.') = '.02C.8)
                                                                     C21243C0
106 FCRMAT (' YD(',12.') = ANGC(',12.') = ',020.8)
                                                                    C2124400
206 FORMAT (' THA(',12,') = Y(',12,') = ',020.8)
                                                                    (2124500
1CE FCFM#T (' YO(',12.') = ThACh(',12.') = '.D20.b)
                                                                     C2124600
              THAM(',12.') = Y(',12.') = ',020.8)
                                                                     (2124700
208 FORMAT ( .
111 FORMAT (' YD(',12,') = YMCC(',12,',',12,',',12,') = ',020.8)
                                                                    C212480C
211 FORMAT (' XMC(',12,',',12,',',12,') = Y(',12,') = ',D2C.8)
                                                                    (2124900
112 FORMAT ( TCTAL NUMBER OF EQUATIONS, NEG = 1.15)
                                                                     C2125000
    SE TUEN
                                                                     C2125100
    END
                                                                     C2125200
```

```
(2200000
C
     SUBRCUTINE OUTPUT
                                                                            (2200100
0
       CENERAL TYPE OUTFUT FOR NO PARTICULAR SATELLITE
                                                                            C2200200
                                                                           C2200300
                                                                            C22C0400
C
      INFLICIT REAL+B(A-F.O-Z.1)
                                                                            C2230500
     LOGICAL FG1. FG2. FG3. FG4. F35. INERF. MOLG. LEGU. LINIT(1)
                                                                           C2200600
C
                                                                            C2200700
                                                                            C22C080C
(
      INTEGEN
                                                                            C2200900
     * ANCRK . CT1 . CT2 . CT3 . CT4 . CT5 . FCUN . PCCN . * SCNCUM. SCN . SCRDUM. SCR . SFKUUM. SFR . SFH . SG .
                                                                           02221000
                                                                         . C2201100
     • SI . 516
                      . SIXDUM. SIX
                                     . SKDUM . SK
                                                       . SL
                                                               . SLK
                                                                        . C2201200
            . SMCJUP, SMC . SMV . SUK . SPIDUM. SPI . SQF
. SH . SSCN . SSIX . SVA . SVE . SVD . SVI
. SVP . SVQ . SXM . SXT . TORQ . SMAL . SEU
. SCG . NFLXB . SFLX . SFXM . NMCDS . SFCC . SCC
     * SMA
                                                              . SOF . C2201300
            . SH
     . SCL
                                                                           (2201400
                                                                        .
     . SVM
                                                                           C2201500
     • SC
                                                                        . 02201600
     . IINIT(1)
                    . IZINIT(1)
                                     . 50
                                                                            C 2 20 1 700
C
                                                                            C2201800
C
                                                                            C2201900
C
                                                                            C2202000
     FE AL . d
                                                                            02202100
     * ANGC (33) , CNF (3.10) , ETIC (3.10) , ETMC (3.10) . 
* FLO (3.20) , FLE (3.3.20), FLM (3.3.20).
                                                                           C2202200
                                                                            C2232300
     . THACD (23) . YHCD (3.2.11). RINIT (1) . RZINIT(1)
                                                                            C2202400
C
                                                                            C2202500
C
                                                                            (2202600
C
                                                                            C2202700
C
                                                                            C2202800
                                                                            C2202900
     COMMEN /LUGIC/ FG1. FG2. FG3. FG4. FG3. INERF. RULU(10)
                                                                            C2223000
                                                                            C2203100
C
                                                                            C2203200
      COMMEN /INTG/ ANDRE (200)
                                                                            C2203300
     • (11
                                      . CT3
                                                       . CT4
                     . CT2
                                                                        . 02203400
                                     . JCGN (10)
     C15
                     . FCUN (33)
                                                       . LCCN (22)
                                                                           02203500
                                                                        .
            (10)
                     . NG1
                                                                        . 02203600
     · MC
                                                       . NCTC
                                      . NFRC
                     . AFKC
                                                       . NLOR
     . NEER
                                                                        . 02203700
                                      . MOA
                     . .
                                                       . NSVP
                                                                       . . (2203800
     . NHV
                     . FCON (111)
                                     . 50
                                                       . SFR (33)
                                                                       . (2273900
     . NEVC
                                                                        . 02204000
                     . $1 (55)
     . 56
                                                       . SL
                     . SMA
                                      . SOK (11)
                                                       . SCF
                             (10)
                                                                        . (2204100
     . SLK
            (23)
                                                                (11)
                                      . SR
     . SGL (11) . SMV
                                                       . SSCN
                                                                        . (2204200
     . SEIX
                     . SVA
                                      . SV8
                                                       . SVD
                                                                           C2234300
                                      . SVP (22)
                                                                        . (2204400
                                                       . SVG (33)
     . SVI
                      . SVM
```

```
* SAM (3.13) . SAT
                                        . TURO (57) . SMAL
                                                                            . 02204500
                       . NTG
                                         • SC (33) • SCG
• SFXM (10) • NMCD
     . SEU
                                                                               C2204600
                                                         . NMCDS
     * NFL XB
                       . SFLX
                                                                               C2204700
     * SFCC
                       . SCC
                                (10)
                                                                                C2204800
                                                                                02204900
C
C
                                                                                C2205000
      CEMMEN /INTGZ/
                                                                                C2205100
                       . SCN
                                        . SCRDUM
     * SCNCLH
                                (5)
                                                          . SCR
                                                                   (9)
                                                                               02225200
     . SFKCLM
                                (5)
                                        . SIXDUM
                                                                            . (2205300
                       . SFK
                                                          . SIX
                                                                  (9)
                      . SK
                                                          . SPI
     . SKOLN
                               (5)
                                         . SPIDUM
                                                                  (9)
                                                                              (2205400
     . SPCCLM
                      . SMC
                                (5)
                                                                                (2205500
C
                                                                                C2205600
C
                                                                                C2205700
      COMMEN /REAL/
                                                                                C2205800
             (3.10) . CAC
(3.11) . ETC
(3.66) . F
(10) . FFI
(3.33) . QL
                                (3.10) . CLM
(3.11) . ETM
                                                       . CCPC (3.11) .
     * CA
                                                 (10)
                                                                               02205900
                                                          . FUMC (3.11)
     . DCMC
                                                 (33)
                                                                   (3.11) · (2206000
(3.10) · (2206100
                                                                               C22060CC
                                                 (3.10) . HMC
     . GAM
                                         . HM
     . ----
                                (3.11)
                                        . PLP
                                                 (10)
                                                         . GF
                                                                   (3.33) . 02206200
     * QFC
                                (3.22) . JLC
                                                 (J.22) . RUMC
                                                                  (3.11) . 02206300
                                                         . THAD (33)
                                           THA
                                                 (33)
                                                                               C220640C
     * THACW (10) . THAW (10)
                                                                   (3,3,10). (2206500
                                        . XDIC (3.3.66) . XI
              (3,3,10), XMAS (10) , XMN (33,33) , XMT (3,3,10), C2206600 (33) , FLA (3,20) , FLB (3,20) , FLC (3,20) , C2206700
     * XIC (3,3,10), XMAS (10)
     . TLG
     * FLD (3,3,20), FLJ (3,3,20), CAO (3,10) , XIC (3,3,10), C2206800

* FLIRC (3,10) , FLCRC (3,10) , FLAC (3,20) , FLQC (3,20) , C2206900

* FLCM (20) , ZETA (20) , FCF (3,3,40), FCK (3,40) , C2207000
     . TIMEND
                                                                                C2207100
C
                                                                                C2207200
C
                                                                                C2227300
      COMMEN /FEALZ/
                                                                                C2207400
                              (3.10) . C3CDUM(1.3) . CBC
     * CEDLM (1.3) . CB
                                                                   (3.10) . (2207500
     * XPCCLM(1.1.9) . XMC (3.3.10). CBN(3)
                                                                                C2207600
C
                                                                                C2207700
C
                                                                               C220780C
      EQUIVALENCE (ETM(1). THACC(1))
                                                .(XMN(1.1).ANGD(1))
                                                                               02207400
                    (XMN(1.2).YMCD(1.1.1))
                                                . (XMN(1.6).LNF(1.1))
                                                                              (2208000
                    (XMN(1.8),ETIC(1.1))
                                                .(XMN(1.10).ETMC(1.1)) .
                                                                               (2208100
                    (FLB(1.1).FLG(1.1))
                                                .(FLE(1.1.1).FLD(1.1.1)).
                                                                               C2208200
                    (FLH(1.1.1),FLJ(1.1.1))
                                                                               02220300
     .
                    (FGI.LINIT(1))
                                                .(CA(1.1).HINIT(1))
                                                                               C2208400
                    (CHDUM(1.1).FZINIT(1))
                                                . (AWORK(1).IINIT(1))
                                                                                C2208500
                    (SCNOLM. IZINIT(1))
                                                                                C2208600
C
                                                                                C2206700
C
                                                                               CZZQRBCO
      INTEGER TIN
                                                                                C2208900
                                                                               02209000
      CIMENSILA PHII(3, 3)
      CIMENSILA TOMC(3.11)
                                                                               C2209100
                                                                               C2209200
      CIMENSICK SYSCM(3)
      CIMENSICH SYSIN(3.3)
                                                                               02229300
      CIMENSICH Hd (3.10). TK(10)
                                                                               C2209400
      CIPENSICH PUS(3,10). VEL(3,10)
                                                                               02209500
      CIMENSICA TEMI(3).TEM2(3).TEM3(3).DEHV(3.11)
                                                                               02209600
      CIMENSICH TEM4(3)
                                                                               (2204700
      CIMENSICA HOCDY(3).
                                   FINERT(3)
                                                                               (2209800
      CIMENSICH EP3(3.10). DHM(3.10)
                                                                               C22C9900
      CIMENSICN EP(3), 61(3.3), EIC(3.3), FUD(3), FODC(3), TEM5(3.3)
                                                                               C2210000
      FEAL +5 LM(3.10).LMT(3)
                                                                               02210100
      INTECER SET(10). SFXPK
                                                                               02210200
                                                                               C2210300
C
                                                                               (2210400
C
```

```
02210500
    1 CENTINUE
      FRIN1 203. T
                                                                          (2210600
                                                                          C221070C
C
                                                                          00801550
C
      COMPLIE SYSTEM COMPOSITE CENTER OF MASS
                                                                          C221C900
C
                                                                          02211000
      TOTM = C.DO
      CO 11 I=1.3
                                                                          C22111CO
                                                                          C2211200
   11 TEMI(1) = 0.00
      CO 15 K=1.NBOD
                                                                          C2211300
      KO = KTC(NH1.0.K)
                                                                          (2211400
      CALL SCLV(XMAS(K).GAM(1.MC).TEM2)
                                                                          C2211500
      (ALL VECADD(TEM1. TEM2.TEM1)
                                                                          02211600
   15 TOTM = TCTM + XMAS(K)
                                                                          02211700
      CC 16 1=1.3
                                                                          C2211800
   16 SYSCH(1) = TEMI(1)/TOTH
                                                                          2211900
      PRINT 200. (SYSCM(1).[=1.3)
                                                                          C2212000
                                                                          02212100
      FRINT 222. TUTM
                                                                          C2212200
C
                                                                          02212300
C
      COMPLTE SYSTEM INERTIA TENSOR AJOUT COMPUSITE CENTER OF MASS
                                                                          C2212400
      CALL SUECP (SYSCM. SYSCM. TCTP. SYSIN)
                                                                          C221250C
      CO 4 1=1.3
                                                                          02212600
      00 4 J=1.3
                                                                          22212700
    4 SYSIN(1.J) = XDIC(1.J.1) - SYSIN(1.J)
                                                                          C2212800
      PRINT 211. (SYSIN(1.J).J=1.3)
                                                                          C2212900
      FRINT 212. (SYSIN(2.J).J=1.3)
                                                                          C2213000
                                                                          (2213100
      PRINT 211, (SYSIN(3,J),J=1,3)
      FRINT 213
                                                                          C2213200
C
                                                                          02213300
                                                                          C2213400
C
                                                                         C2213500
C
     COMPLIE VECTOR FROM INERTIAL ORIGIN TO COMPOSITE SYSTEM
                                                                       (2213600
      CENTER OF MASS RELATIVE TO COMPUTING FRAME
C
      CALL VECADDICEC(1.1), SYSCM, CHC(1.0))
                                                                          C2213700
                                                                          (221 3800
C
C
                                                                          02213900
                                                                          C2214000
C
C
      FLEXIBILITY RELATED PARAMETERS
                                                                          (2214100
                                                                          00241553
      MN = 3
      CO 3C K=1.NECD
                                                                          C2214300
      CO 32 1=1.3
                                                                          22214400
      EPD(1.K) = 0.
                                                                          C2214500
   32 CHM(1.K) = 0.
                                                                          02214600
      IF (SFXM(K).EU.C) GC TO 3C
                                                                          C22147CO
      SFANK = SFXM(K)
                                                                          00841552
      CO 31 1=1.SFX#K
                                                                          C221490C
      NN = MN+1
                                                                          (2215000
      NEWN = NEER + MN
                                                                          C2215100
      (ALL SCLV(THAD (NFPN), FLAC(1,MN), TEM1)
                                                                          C221520C
      CALL VECADD(EPD(1.K).TEMI.EFD(1.K))
                                                                          C2215300
      (ALL SCLV(THAD(NFMN).FLQC(1.MN).TEM1)
                                                                          C2215400
      CALL VECADD(CHM(1.K).TEM1.DFM(1.K))
                                                                          C2215500
   21 CONTINUE
                                                                          C2215600
   3C CONTINUE
                                                                          C22157CO
C
                                                                        G2215800
C
                                                                          02215900
C
                                                                          02216000
C
      COMPLIE INERTIAL ANGULAR MEMENTUM AND KINETIC ENERGY OF EACH
                                                                          02216100
C
       ECCY AND OF THE COMPOSITE SYSTEM
                                                                          C2216200
      TKIN = C.DO
                                                                          C2216300
      CO 7 1=1.3
                                                                          C2216400
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LMT(1) = 0.00
                                                                          02216500
    7 +0CDY(1) = 0.DC
                                                                          02216600
      CO 17 AKK=1. NOLD
                                                                          02216700
      K=NBCC-(KKK-1)
                                                                          02216800
      KK = K
                                                                          (2216900
      JK = JCCN(K)
                                                                          (2217000
      IF (KK.NE.1) GO TO 28
                                                                          C2217100
      CC 25 1=1.3
                                                                          02217200
   29 TEM1(1) = RUMC(1.NE1)
                                                                          C2217300
      GC TC 2c
                                                                          (2217400
   2E CONTINUE
                                                                          02217500
      COMPLIE LINEAR VELOCITY OF CENTER OF MASS OF BUDY & PUT IN TEMT
      IF (PELU(K)) GO TO 19
                                                                          C2217700
      CALL VECTOS (FEME(1.JK).CAC(1.K).TEM1)
                                                                          (2217800
      CALL VECAUDIRUMC(1.K). TEA1. TEM1)
                                                                          02217900
      GU TC 24
                                                                          02218300
   15 CALL VECFUS (FCMC(1.K).CAC(1.K).TEM1)
                                                                          (2218100
   24 CALL VLCADD(RCMC(1.NH1).TENI.TEMI)
                                                                          00291350
      CHECK FLH LND OF CHAIN
                                                                          C221 6300
   25 IF (JK.EG.0) GC TO 26
                                                                          C2218400
      CALL VECKUS (FLMC(1.JK).CEC(1.KK).TEM2)
                                                                          02218530
      CALL VELAUDITEMI. TEM2. TEMII
                                                                          (2218600
      KK = JA
                                                                          (2218700
      JK = JCCN(KK)
                                                                          C221H600
      CC TL 25
                                                                          C2218900
   26 CENTINUE
                                                                          02219000
C
                                                                          02219100
      INTERTIAL PUSITION OF CENTER OF MASS IN TEM2
                                                                         (2219200
      KL = KTC(NB1.0.K)
                                                                          02219300
      CALL VECADD(CEC(1.1).GAM(1.KL).TEM2)
                                                                          (2219400
     CO 3 1=1.3
                                                                         C2214500
      FCS(I.A) = TEM2(I)
                                                                          (2219600
   2 VEL(I.K) = TEMI(I)
                                                                          02215700
                                                                          02214800
      ADD RELATIVE VELOCITY OF CM. NUN-ZERU IF BODY FLEXIBLE
C
                                                                          12216900
     CALL VECADO(VEL(1.K).EFD(1.K).VEL(1.K))
                                                                         02222000
      co 13 1=1.3
                                                                          02122552
   13 TENI(I) = VEL(I.K)
                                                                          (2220200
C
                                                                          022220300
C
                                                                          022220400
     START CLAPUTATION OF ANGLLAR NUMENTUM. LINEAR MUMENTUM AND KINETICC2220500
      CALL LYLLTV(XIC(1.1.K).FCMC(1.K).HE(1.K))
                                                                          C2220600
      (ALL VECELT(FEMC(1.K).HE(1.K).TK(K))
                                                                          (2220700
      CALL VECCUT(TEMI.TEMI.TEM
                                                                          228220800
      TK(K) = .DDD=(TK(K) + XMAS(K)=TEM)
                                                                          02950900
      CALL VECTOS (TEM2.TEM1.TEM3)
                                                                          12221000
      CALL SCLV(XMAS(N).TEM3.TEM3)
                                                                          02221100
      (ALL VECADO(FE(1.K).TENJ.HE(1.K))
                                                                          02221200
      IF ( . NOT . FELU (K)) GC TO 27
                                                                          (2221300
      IF (NNO.EG. 0) GO TC 5068
                                                                          02221400
      DMM.1=4 75 02
                                                                          02221500
      IF (MC(N).NE.K) GO 10 27
                                                                          02221600
      (ALL SCLV(HMOM(M). HMC(1.A). TEAS)
                                                                          C2221700
      CALL V= CALD[HE(1.K).TENJ.HE(1. ))
                                                                         02811800
      TK(K) = TK(K) + . SCO *HMC *(M) ** 2/PLM(M)
                                                                          00612223
  27 CCATINUE
                                                                          C222200
                                                                          C2 . 1 . 1
STEE CONTINUE
                                                                         0.53
C
                                                                         Ca. 2100
C
      ADE FLEXIBILITY ACCITIONS TO MOMENTUM AND ENERGY
                                                                         0222240
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CALL VECADD(HE(1.K). DHM(1.K).HJ(1.K))
                                                                           C2222500
     CALL VECCCT(FCFC(1.K).CHF(1.K).TEN)
                                                                           02222600
      TK(K) = TK(K) + TEM
                                                                           (2222700
                                                                           C2222800
                                                                           C22229C0
     ADD UP FOR SYSTEM ANGULAR MOMENTUM AND KINETIC ENERGY
                                                                           02223000
      TKIN = TKIN + TK(K)
                                                                           C2 223100
     CALL VECADD(FU(1.K).HBCDY.FEODY)
                                                                           C222 1200
      CALL SCLV(XMAS(K) .VEL(1.K).LF(1.K))
                                                                           C222330C
     CALL VECACOLLHT.LN(1.K).LNTS
                                                                           02223400
                                                                           C2223500
   17 CENTINUE
      CALL THREPS (XMC(1.1.C))
                                                                           C222360C
      (ALL VECTEN (HOODY.XMC(1.1.0).HINERT)
                                                                           C2 223 700
      (ALL THRSPS (XMC(1.1.0))
                                                                           C2223800
      IF ( . NCT . INCKF) GO TO 2
                                                                           (2223900
      CALL THREPS (XMC(1.1.1))
                                                                          C2224200
      (ALL VECTEN (HINERT.XMC(1.1.1).HBJDY)
                                                                           C222410C
      (ALL THASPS (XMC(1.1.1))
                                                                           C2224200
   2 CONTINUE
                                                                           C2224300
     HMG = DEGRT(HINERT(1) ** 2 + FIRERT(2) ** 2 + HINERT(3) ** 2)
                                                                          C2224400
     FRINT 205. HMG
                                                                           C2224500
     FRINT 201. (FEGDY(1).1=1.3)
                                                                           (2224600
     FRINT 202. (HINERT(1),1=1.3)
                                                                           C2224700
      A = CSGRT(LMT(1)**2 + LMT(2)**2 + LMT(3)**2)
                                                                           C222483C
     PRINT 217. A
                                                                           C2224900
     FRINT 215. (LMT(1).1=1.2)
                                                                           (2225000
     FRINT 215. TKIN
                                                                           C2225100
C
                                                                           C2225200
                                                                           C2225300
     COMPLIE INENTIAL ACCELERATIONS
                                                                           (2225400
      CO 8 1=1.3
                                                                           02225500
   £ TOMC((1.1) = DCMC((1.1)
                                                                           C2225600
      IF (NECJ.EQ.1) GO TO SOCI
                                                                           C2225700
     CO 14 K=2.NBUD
                                                                          C2225800
      CALL VECTOS (FCMC(1.K). HCMC(1.K). TEM1)
                                                                           C2225900
  14 CALL VECSUBIDOMC( I.K) . TEN1 . TCMC(1.K))
                                                                           C2220000
SCCI CONTINUE
                                                                           02226100
      (ALL VECFOS (FOMC(1.1).ACMC(1.NUI).TEMI)
                                                                           02226200
      CALL VECSUB(DGMC(1.NB1). TEM1.TCMC(1.Nd1))
                                                                           C222630C
     W = 1
                                                                           C2226400
      CO 2C K=1.NB1
                                                                           C222650C
      IF (K . E 3 . 1) GO TO 21
                                                                           C2226600
      * = *+3-FCJN(K-1)
                                                                           C22267CC
  21 00 22 1:1.3
                                                                           C22268CC
  22 TE+1(1) = 0
                                                                           C2226900
     WMTERMEN 42-PCON(K)
                                                                           C2227COC
      IF (M.GT.MMTERM) GC TO 20
                                                                           C2227100
     CC 23 MM=M.MMTERM
                                                                           C222720C
     CALL SCLV(THADD(MN).QFC(1.MM).TEM21
                                                                           C2227300
  23 CALL VECADO(TEMI.TEM2.TEMI)
                                                                          C2227400
  20 CALL VECADU( TEMI. TOME (1.K) . DERV(1.K))
                                                                          C2227500
                                                                           C2227600
                                                                           C22277CC
     CC 5 K=1.NOUD
                                                                          02227800
     PRINT 204. K.(ROMC([.K).[=1.3).(FOMC([.K).[=1.3)
                                                                           C2227900
  10 PRINT 207. (DERV(1.K). [=1.2)
                                                                          02228000
     PRINT 223. (ETC(1.K).1=1.3).(PHI(1.K).1=1.3)
                                                                          C222810C
     PHINT 2CE. (CAC(I.K). [=1.3).(CJC(I.K). [=1.3)
                                                                          (2228200
     PRINT 216. (PCS(1.K).1=1.3).(VLL(1.K).1=1.3)
                                                                          C2228300
     FRINT 200. ((XMC(1.J.K).=1.3).(XIC(1.J.K).J=1.3).1=1.3)
                                                                          C2228400
```

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FRINT 214. (H6(J.K).J=1.3).1K(K)
                                                                             C2228500
     FRINT 21t. (LM(J.K).J=1.2)
                                                                             02223600
   E CONTINUE
                                                                             C2228700
     PRINT 208. (FOMC(1.NBI).1=1.3).(DERV(1.NBI).1=1.3)
                                                                             (2228600
     FRINT 223. (ETC(1.NBI).[=1.3).(PHI(1.NBI).[=1.3)
                                                                             022228900
     FRINT 224. (CEC(1.C).1=1.3)
                                                                             (2229000
     FRINT 221. ((XMC(1.J.0).J=1.3).1=1.2)
                                                                             (2229100
     PRINT 213
                                                                             C2229200
     IF (N#J.EG.O) GC TC 41
                                                                             C2229300
     CO 6 #=1.NMU
                                                                             C222940C
     FRINT 21C. M.HMOH(N).W.CLM(N)
                                                                             C22295CC
                                                                             C22296C0
   & CONTINUE
  41 CONTINUE
                                                                             C2229700
     PRINT 213
                                                                             C222480C
     IF (NPCDS.EU. 0) GO TO 40
                                                                             (2229900
                                                                             C2230000
     CALL UNPACISET.NSET.SFLX1
                                                                             C223010C
     MN = 0
     20 33 KK=1.NSET
                                                                            C2230200
     K = SET(NSET+1-KK)
                                                                             (2230300
     CO 34 1:1.3
                                                                            C2230400
     EP(1) = C
                                                                            (2230500
     FOC(1) = 0
                                                                             C223060C
     FGCC(1) = 0
                                                                            C2230700
     CO 34 J=1. J
                                                                             C2230800
     E1(1.J) = 0
                                                                            C2230900
     E10(1.J) = 0
                                                                             02231000
  34 CCATIANE
                                                                            02231100
     SFXMK = SFXM(K)
                                                                             02231200
     CO 35 M=1. SF XMK
                                                                            22241300
     PN = PA+L
                                                                            C2231400
     NENN = NEER+MA
                                                                            C2231500
     CALL SCL V (THA (NFMN) . FLA(1. MN) . TEMI)
                                                                             C223160C
     (ALL VECADDIEP . TENI.EP)
                                                                            C2231700
     (ALL SCLV(THAD(NFMN).FLQ(1.PN).TEMI)
                                                                            00016353
     CALL VECADD(FQD.TEMI.FGC)
                                                                            C2231900
     CALL SCLE (THA (NFMN). FLE(1.1.NN). TEME)
                                                                            C2232C00
     (ALL CYACDIE 1. TEME.EI)
                                                                            02232100
     CALL SCLE(THAD(NFMA).FLE(1.1.4N). FEMS)
                                                                            C2232200
     CALL DYALD(EID.TEMS.EID)
                                                                            C2232300
35 CONTINUE
                                                                            C22324CC
     PRINT 226. (EP(1).1=1.3).(EFD(1.K).1=1.3)
                                                                            C2232500
     FRINT 226. K. (FQD(1).1=1.3)
                                                                            C2232600
    FRINT 225. ((E1(1.J).J=1.3).(E10(1.J).J=1.4).1=1.3)
                                                                            02232700
    FRINT 430. (FLIRC(1.K).1=1.3).(FLCHC(1.K).1=1.3)
                                                                            02832800
     FRINT 221. (CHM(1.K).[=1.3)
                                                                            C2232400
                                                                            :2233000
  33 CONTINUE
     FRINT 213
                                                                            (2233100
  AC CONTINUE
                                                                            (2233200
                                                                            C2233300
     CO 9 1=1.NFEH
   9 FRINT 22C. (1.THA(1).1.THAD(1).1.THADD(1).1.(UFC(J.1).J=1.3))
                                                                            C2233400
    MI = NFEF+1
                                                                            C223350C
    N2 = NFEF+MN
                                                                            C2233600
     IF (MA .EG . C) HE TURK
                                                                            C22337C0
    SM. 14 1 = N1 . N2
                                                                            C2233800
  12 FRINT 225. 1. THA(1).1. THAD(1).1. THADO(1)
                                                                            C2233900
200 FORMAT ( * CENTER OF MASS = 1.3017.0./)
                                                                            C2234000
201 FORMAT (/, 3x. 'HOCDY = '.3C17.d)
202 FORMAT (3x. 'HINERT = '.3D17.d)
                                                                            C223410C
                                                                            C2234200
203 FORMAT ('1 TIME = '.DIE.E./)
                                                                            C2234300
204 FORMAT(/.3x.'BCDY '.12.4x.'FOMC ='.3017.d.3x.'FCMC ='.3017.8)
                                                                            C2234400
```

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205 FCHMAT (14x. 'CAC = '.3017.8.3x, 'CBC = '.3017.8)
                                                                        (2234500
2CE FCRMAT (14x. 'XMC = '.3D17.8.3X. 'XIC = '.3D17.8)
                                                                       C2234600
207 FURMAT (14X. 'ACC = 1.3017.8)
                                                                       C22347CO
2CE FORMAT (/.JX. 'ORIGIN'.4X. 'F(NC = '.JD17.J. 3X. 'ACC = '.JD17.E)
                                                                       C22348C0
205 FORMAT ( ANGULAR MOMENTUM = 1.020.8)
                                                                        C2234900
21C FORMAT (3x, 'HMOM(',12,') = ',D17.8,10x,'CLM(',12,') = ',D17.8)
                                                                       (2235000
211 FCRMAT (25x. 3D17.d)
212 FORMAT (' SYSTEM INERTIA TENSOR =',3017.8)
213 FORMAT (' ')
                                                                        C2235200
                                                                        C2235300
214 FORMAT(14x. Hd = '.3017.8.3x. TK = '.017.8)
                                                                        C2235400
215 FORMAT (/. KINETIC ENERGY = '.D20.8)
                                                                       (2235500
216 FCRMAT (14x, 'PCS = '.3C17.8.3x, 'VEL = '.3D17.8)
                                                                       (2235600
217 FORMAT (/. LINEAR MCMENTUM = 1.020.8)
                                                                        (2235700
21E FORMAT (14x. ' LM = '.3017.6)
                                                                        C2235800
215 FORMAT (/. DX. 'LOUCY = '.301/.8)
                                                                        (2235900
22C FORMAT (3x, 'THA(', 12, ') = ', D13.6, 3x, 'THAD(', 12, ') = ', D13.6, 3x, 'THAC22360CC
  *CD('.12.') ='.D13.6.3x.'(F(('.12.') ='.3013.6)
                                                                       02236100
221 FORMAT (14x. 'XMC = '.3017.8)
222 FORMAT (' TOTAL SYSTEM MASS = '.DI7.d./)
                                                                        02236300
223 FORMAT (14x. 'ETC = 1.3017.6.3x. 'PHI = 1.3017.8)
                                                                       C2236400
224 FURMAT (14x, 'CdC = ',3017.8)
                                                                        (2236500
225 FURMAT (3x, 'THA(',12,') =',013.0,3x,'THAD(',12,') =',D13.6,3x,'THAC2236600
                                                                        02236700
   *CC(',12.') ='.D13.6)
226 FCRMAT (/.3x. FLEx16LE '.3x. CP = '.3017.8.3x. EPP = '.3017.8)
                                                                       C2236H00
22E FORMAT (3x. BODY'.12.4x. CD = '.3017.8)
                                                                       C2236900
225 FCRMAT (14x. ' E1 = '.3D17.8.3x. 'E10 = '.3D17.8)
                                                                       02237000
23C FCRMAT (14x. 'FIR = '.3C17.6.3x, 'FCR = '.3C17.0)
                                                                       (2237100
231 FORMAT (14x, 'DHM = ',3017.8)
                                                                        C223720C
    FE TUEN
                                                                       (2237300
    END
                                                                       C2237400
```

```
C
                                                                 (2300000
    SLEECLTINE JUTPSP
                                                                 (2300100
C
      GENERAL TYPE GUTFUT FOR NO PARTICULAR SATELLITE
                                                                 C2300200
C
                                                                 02300300
C
                                                                 00400553
     IMPLICIT HEAL OH (A-H.U-Z.1)
                                                                 (2300500
    LCCCCAL FG1. FG2. FG3. FG4. F33. INERF. RELC. LEDU. LINIT(1)
                                                                 02300600
C
                                                                 C2330700
                                                                 02330800
                                                                 0.0000523
     INTEGER
    • ANDFK , CT1 , CT2 , CT3 , CT4 , CT5 , FCCN , PCCN , C2301000
    * SCNEUN, SCN , SCROUN, SCR , SFKOUM, SFK , SFR , SG
                                                              . (2301100
                                 SCK SPIDUM SPI SQF
                                                                C2301200
                                . SKOUN . SK
    • $1 . SIG
                  . SIXDUM . SIX
    . SVA
           . SMLDUN. SMC . SMV
                                                                02301300
    . SGL
           . SM . SSCN . SSIX . SVA
                                       . SV8 . SVD . SVI
                                                              . 02301400
          . SVP
                                 . SXT
                                                              . 02301500
    . SVM
                 . SVQ . SXM
                                       . TORG . SMAL . SEU
           . SCG . NFLX8 . SFLX . SFXM . NMUDS . SFCC . SCC
    . 50
                                                              . (2301600
    · IINIT(1)
                  . 121NIT(1)
                                 . 50
                                                                 C2301700
c
                                                                 C2301800
C
                                                                 02301900
0
                                                                 02202000
     FE AL . H
                                                                 02302100
    • ANGC (23)
                  . (NF (3.10) . ETIC (3.10) . ETMC (3.10) . (2302200
    • FLO (3.20) • FLE (3.3.20) • FLH (3.3.20) •
                                                                025305300
                                              . WZINIT(1)
    • THACO (23) . YMCD (3.2.11). RINIT (1)
                                                                0.0450523
```

```
C
                                                                     02302500
C
                                                                     02302600
C
                                                                     (2332700
C
                                                                      0.0850553
C
                                                                     (2302900
     COMMON /LUGIC/ FG1. FG2. FG3. FG4. FG5. INCAF. HELU(10)
                                                                     02303000
C
                                                                     02303100
                                                                     02303200
     CCHMEN /INTG/
                     ##ORK (200)
                                                                     C2333300
                                   • CT3
                    . C12
                                                  . (14
                                                                  . (2303400
     * CT1
                    . FCON (33)
                                   . JCEN (10)
     · C15
                                                . LLLIN (ZZ)
                                                                  . 02303500
     . ..
            (10)
                    . NE1
                                    . N300
                                                   . NETC
                                                                  . 02303600
     . NFER
                    . NFKC
                                    . NERG
                                                   . Neuk
                                                                     C23037C0
                    . NAC
                                    . NHUA
                                                   · Novi
     . NAV
                                                                     C2303600
     . NEVC
                    . FLON (11)
                                   . SL
                                                  . 51 + (33)
                                                                  . (2303900
                                                  . JL
. Jul (11)
     * SG
                           (55)
                                   . 210
                                                                  . (2304000
                    . 21
                                    . JUN (11)
     . SLK
            (23)
                    . SMA
                           (10)
                                                                     02304100
                                                   . Sich
     · SCL
            (11)
                    . SNV
                                    . 55
                                                                     02324200
                                                   . SVC
                    . SYA
                                    · SVB
     . SSI>
                                                                     (2304300
                                   . SVI 1221
                                                  . avc (33)
     * SVI
                    . SVM
                                                                     02304400
                                    . TOTA (17)
                                                  · SMAL
     * SXM
            (3.10)
                    . SAT
                                                                     (2304500
     * SEU
                    . NTO
                                   . 50
                                           (11)
                                                                     02304600
                                                   . 544
     . NEL 33
                    . SFLX
                                    . SFXM 1101
                                                                  . 02304700
                                                   . AMILS
     . SFCC
                    . SCC (10)
                                                                     C2324800
                                                                     02334900
C
                                                                     (2305000
     COMMEN /INTGZ/
                                                                     (2335100
                                                 , 566 (9)
                                  . SCI-UJM
     · SCNEUM
                                                                 . (2305200
                   . SCN
                          (5)
                                                  • 1× (9)
                                  . SINUUM
                                                                 . 02205300
     . SFKELM
                   . SFK
                          (5)
                                                                  . 02205400
                    . SK
                                   · SPIDUM
     * SKOLN
                           (5)
     . SMCCL4
                    . SMC
                            (4)
                                                                     02305500
                                                                     02305600
0
                                                                     02305700
     COMMEN THEALT
                                                                     (2305800
    + CA (3.10) . CAC
+ DCMC (2.11) . ETC
                           (3.10) . CLW
                                           (10) , COMC (1.11) , C2375900
                                                   * I'LML
                                   , Hid
            (3 · .) . F
                                                          (3.10) . (2306100
     * GAM
                                           (1.10) . HMC
     . HNCH (1.1 . FHI
                                                  . 41
                           (2.11)
                                  · PLM
                                          (40)
                                                          (3.33) . (23)6200
                                                  LOME
            (3.32) . GL
     · GFC
                           (3.22) , OLC
                                           (3.22)
                                                          (3.11) . 02306300
                                                   . THAU
    * THACW (10)
                                     THA
                                           ( 53)
                                                          (33)
                                                                     02306400
                    . THAN (10)
                                                          (3.1.10). (2306500
                                   . XDIC (3.3.00) - XI
                                   . XMN
     * XIC (2.3.17) . XMAS (10)
                                           (33.33) . XMT (3.1.10). (2306600
            (33) , FLA
                                           (1.20) . FLC (3.20) . (2306700
                           (3.20) . FLU
     · TLG
    ■ FLC (3.3,20), FLJ (3.3,20), CAO (3.10) , AIL (2.3,10), C2306800

■ FLIFC (3.10) → FLCRC (3.10) → FLAC (3.20) → FLUC (2.20) → C2306900
                                  · FCI
     * FLC+ (20) . ZETA (20)
                                           (3. 1.40) . FEN
                                                          (3.40) . 02307000
     . TIMENO
                                                                     C2337100
C
                                                                     02307200
C
                                                                     02307300
     COMMEN /FEAL 2/
                                                                     (2307400
    . CEDLY (1.3) . CE
                           (3.10) . COCOUM(1.3) . CBC (3.10) . C2307500
     * X . CCLM(1.1.5) . XMC
                           (3.3.10). Can(3)
                                                                     02307600
C
                                                                     (2307700
                                                                     02307800
C
     EQUIVALENCE (LTM(1), THADC(1))
                                         . (XMN(1.1). ANGD(1))
                                                                    02307900
                                          . (AMN(1.0).CNF(1.1))
                                                                    02308000
                 (XMN(1.3).YMCD(1.1.1))
                                          .(AMN(1.0).CNF(1.1)) .
                 (XMN(1,8), ETIC(1,1))
                                                                     C230H100
                                          ·(FLE(1.1.1).FLD(1.1.1)).
                 (FLB(1.1).FLG(1.1))
                                                                     02308200
                 (FLH(1,1,1),FLJ(1,1,1))
                                                                    (2308300
                                          . (CA(1.1).41N1T(1)) .
                 (FGL.LINIT(1))
                                                                   C233H40C
```

```
(CUDUM(1-1).621N1T(1)) .(AWGHK(1).11NIT(1))
                                                                           (2308500
                  (SCHOLM, 1/16 IT (11))
                                                                            (2308600
                                                                            C2308700
                                                                           02308800
C
                                                                            (2308900
      CIMENSILA PHILL(3. 1)
                                                                           00000053
      CINENSICA ILMETALIA
                                                                            02309100
      CINENSIEN SYSCHEST
                                                                            0.029000
      CIMENSICK SYSTNIJ.31
                                                                           02309300
      DIMER-ILA HO(J.10). TK(IC)
                                                                           00490553
      CIPER. LEN POSCOLICIEVELLO.ICI
                                                                           02309500
      CIMENSICA TEMI(3) .TEMP(3).TEMB(3) .DERV(3.11)
                                                                           0.049.05.53
      CINENSION TENALS!
                                                                           02309700
                             FINERI(2)
      CIMEN: ILA HOUDY (3).
                                                                           0.0360523
      CINENSILA LPOLDITCHINANCA, 10)
                                                                           (2309900
      TIME NOTE & EP (3): 1(3,3), (1( (7,4), ELD(3), FODC(3), TEM5(3,3)
                                                                           020310000
      INTECES SETCIOLOSEXMA
                                                                           02310100
      HE AL +4 LA(3,10). LAT(3)
                                                                           02310200
      INTE CER TIK
                                                                           (2310300
                                                                           02310400
                                                                           02310500
    1 CCATINI
                                                                           (2310600
      FRINT LOS. T
                                                                           02310700
C
                                                                           02310800
\epsilon
                                                                           02310900
     COMPLIE SYSTEM COMPOSITE CENTER OF MASS
                                                                           02311000
(
      TO II I=1.3
                                                                           02311100
                                                                           0.0211200
   11 1501(1) 2.00
                                                                           02311300
      CO 15 K=1 . NHCD
                                                                           12311400
      KO = KIC(NOL . O . K)
                                                                           C2311500
      (ALL SULVERANCE) . AMELIACE . TEME)
                                                                           00011553
      CALL VECADD ( TEMI. TEMZ. TEMI)
                                                                           C2311700
   1: TOTM - TELM + XMAS(K)
                                                                           0.2311800
      CO 16 1=1.3
                                                                           02211900
   16 SYSCMILL - TEMICITATETA
                                                                           02212000
      FRINT 200. (575LM(1).1-1.1)
                                                                           02312100
      FAINT ECC. ILIM
                                                                           002312200
                                                                           02212300
0
                                                                           (2312400
6
     CUMPLIC VECTOR FREM INTERTIAL STIGIN TO COMPOSITE SYSTEM
                                                                           (2312500
C
       CENTER IT MASSIFICATIVE TO COMPUTING FRAME
                                                                           C231260C
      CALL VECALDICECTION, ASCARCHETTON
                                                                           02312700
                                                                           00921252
                                                                           22312900
C
      CHAPLE LYSIEM INCHILA TENSIH ABOUT COMPUSITE CENTER OF MASS
                                                                           00001650
      CALL EULIPERY CH. TSCH. CTA.STUINI
                                                                           (2313100
      [1] 4 | 1 1.1
                                                                           ( 2313200
       50 4 3 1.3
                                                                           C2313300
    4 SYSTACL AND - ROTCELLAND SYNTHEIN
                                                                           C2313400
      C2313500
      FRINT ZIZA LSYSINIZATIAJELAZI
                                                                           02313600
      FRINT . II. LOVOINGS. 11 . J - 1 . 21
                                                                           C231 1700
      FRINT 21
                                                                           C2313800
                                                                           C231 3900
                                                                           02314000
C
      FLEXIBILITY BLEATER PAGANETERS
                                                                           02314100
C
      MN = 0
                                                                           00241620
      CO IC #= 1. NOUF
                                                                           (2314300
                                                                           C2314400
      CG 3. 1:1.5
```

```
C2314500
      EPO( 1.K) = 0.
   32 CHM( I.K) = 0.
                                                                           02314600
                                                                           C2314700
      IF (SFX4(K).LU.C) GU TO 3(
      SFXNK = SFXM(K)
                                                                           C2314800
                                                                           02314900
      DO 31 I=1.SFAMK
                                                                           02315000
      NN = MV+1
      NEWN = NEER + MN
                                                                           (2315100
      (ALL SCLV(THAD (NFMA) .FLAC(1 .MN) .TEMI)
                                                                           02315200
      CALL V=CADD(EPD(1.K).TEN1.EFD(1.K))
                                                                           C2315300
                                                                           (2315400
      CALL SCLV(THAD (NEWN) .FLOC(1.MN) . TEM1)
      (ALL VECADD(DHM(1.K).TEN1.DHM(1.K))
                                                                          (2315500
   31 CCATINUE
                                                                           C2315600
   3C CONTINUE
                                                                           C2315700
                                                                           C231580C
C
                                                                           02315900
                                                                           (2316000
C
C
      COMPLTE INERTIAL ANGULAR MEMENTUM AND KINETIC ENERGY OF EACH
                                                                           C2316100
C
        EDEY AND OF THE COMPOSITE SYSTEM
                                                                           02316200
      TKIN = C.DO
                                                                           C2316300
     CU / 1=1.3
                                                                           C2316400
     LMI(I) = C.UC
                                                                           02316500
    7 +8CDY(1) = 0.DC
                                                                           02316600
                                                                           C23167CC
      CO 17 KKK=1.NBCD
      K=NBCJ-(KKK-1)
                                                                           C2316800
      KK = K
                                                                           02316900
      JK = JULN(K)
                                                                           C2317000
      IF (KK.NL.1) GC TO 28
                                                                           C2 31 71 CO
      10 29 1=1.3
                                                                           02217200
   25 TEM1(1) = HUMC(1.NE1)
                                                                           (2317300
     60 TC 26
                                                                           (2317400
   26 CENTINUE
                                                                           C2317500
      COMPLET LINEAR VELECITY OF CENTER OF MASS OF GUDY & PUT IN TEMT
                                                                          02317600
      IF (RELUCK)) GU TO 19
                                                                           C231770C
      CALL VECTOS (FCMC(1.JK).CAC(1.K).TEM1)
                                                                           C2317800
      (ALL VECADD(HUMC(1.K), TENI, TEMI)
                                                                           C2317900
      CO TC 24
                                                                           02318000
   IS CALL VECFOS (FEMC(1.K), CAC(1.K), TEMI)
                                                                           02318100
   24 (ALL VECADD(HOMC(1.NBI).TEM1.TEM1)
                                                                           02318200
      CHECK FOR END OF CHAIN
                                                                           C23183CC
   25 IF (JK.EG.0) GU TU 26
                                                                          C2318400
      CALL VELAUS (FCMC(1.JK).CEC(1.KK).TEM2)
                                                                          02318500
      CALL VECADOLTEMI. TEMP. TEMI)
                                                                          02318600
      KK = JK
                                                                           02318700
                                                                          C231H800
      JK = JCLN(KR)
      CC TC 25
                                                                          02218900
                                                                          C2219000
   26 CUNTINUE
                                                                           02319100
C
                                                                          C2319200
C
      INTERTIAL PUSITION OF CENTER OF MASS IN TEME
      KL = KTO(NEL . C . K)
                                                                          C2319300
      (ALL VECACO (CBC(1.1).GAM(1.KL).TEM2)
                                                                          C2319400
                                                                           C2319500
      CO 3 1=1.3
                                                                          72319600
      FUSILIAN) = TEMP(I)
    3 VEL(I.K) = TEMI(I)
                                                                          C2319700
                                                                          C2319830
C
                                                                          C2319900
C
     ACC FELATIVE VELUCITY OF CM. NUN-ZERO IF BODY FLEXIBLE
                                                                          (2320000
C
      (ALL VELADU(VEL(1.K).EFC(1.K).VEL(1.K))
                                                                          02320100
                                                                          .2320200
      CO 13 1=1.3
  13 TEMI(1) = VEL(1.K)
                                                                          02320300
                                                                          C2320400
```

```
C
      START CUMPUTATION OF ANGLLAR MUMENTUM, LINEAR MUMENTUM AND KINETICC2320500
      CALL DYDETV(XIC(1,1,K),FC+C(1,K),HB(1,K))
                                                                           00302553
      (ALL VECCGT(FGMC(1.K).HE(1.K).TK(K))
                                                                           C2320700
      CALL VECCOT(TEMI.TEMI.TEM)
                                                                           (2320800
      TK(K) = .500*(TK(K) + XMAS(K)*TEM)
                                                                           C23209C0
      CALL VECTOS (TEM2.TEM1.TEM3)
                                                                           02321000
      (ALL SCLV(XMAS(K).TEM3.TEM3)
                                                                           C2321100
      (ALL VECADD(HE(1.K).TEM3.+8(1.K))
                                                                           C2321200
      IF (.NOT.RULU(K)) GC TO 27
                                                                           C232130C
      IF (NMC.EU.O) GC TC 5068
                                                                           00415553
      CO 27 #=1.NMO
                                                                           C2321500
      IF (MC(M).NE.K) GJ TO 27
                                                                           C2321600
      (ALL SCLV(HMOM(M),HMC(1.N),TENJ)
                                                                           C2321700
      CALL VECADD(HB(1.K). TEN3.FE(1.K))
                                                                           02321800
      TK(K) = TK(K) + .500*HMC+(M)**2/PLM(M)
                                                                          (2321900
   27 CENTINUE
                                                                           C2322000
 SODE CONTINUE
                                                                           02322100
C
                                                                           0.055553
C
                                                                           C2322300
C
      ADD FLEXIBILITY ADDITIONS TO MUMENTUM AND ENERGY
                                                                          02322400
      CALL VECADD(Hb(1,K),DHM(1,K),HJ(1,K))
                                                                           C2322500
      CALL VECCCT(FUMC(1.K).DHM(1.K).TEM)
                                                                           02322600
      TK(K) = TK(K) + TEM
                                                                           C2322700
C
                                                                           C2322800
C
                                                                           02322900
      ACC LP FCR SYSTEM ANGULAR MCMENTUM AND KINETIC ENERGY
                                                                           C2323000
      TKIN = IKIN + TK(K)
                                                                           C232310C
      (ALL VECADD(FE(1.K).FBCCY.FECDY)
                                                                           C2323200
      CALL SCLV(XMAS(K) . VEL(1.K) . LM(1.K))
                                                                           C2323300
      (ALL VECADD(LMT.LM(1.K).LMT)
                                                                           (2323400
   17 CONTINUE
                                                                           C2323500
      (ALL THNSPS (XMC(1.1.C))
                                                                           C2323600
      CALL VECTRN (HEODY, XMC(1.1.C), HINERT)
                                                                           (2323700
      (ALL TENSPS (XMC(1.1.0))
                                                                           C2323800
      IF ( . NOT . INERF) GU TO 2
                                                                           C2323900
      (ALL TRNSPS (XMC(1.1.1))
                                                                           12324000
      CALL VECTEN (HINERT.XMC(1.1.1).H20DY)
                                                                           C2324100
      CALL TRASPS (XMC(1.1.1))
                                                                           (2324200
    2 CONTINUE
                                                                           C232430C
      FMG = DSGRT(HINERT(1)**2 + FINERT(2)**2 + HINERT(3)**2)
                                                                           C2324400
      FRINT 205. HMG
                                                                           C2324500
      PRINT 201. (HECDY(1).1=1.2)
                                                                           C2324600
      FRINT 202. (HINERT(1).1=1.2)
                                                                           C2324700
      A = CSGHT(LMT(1)**2 + LMT(2)**2 + LMT(3)**2)
                                                                           C2324800
      FRINT 217. A
                                                                           02324900
      FRINT 215. (LMT(1).1=1.3)
                                                                           (2325000
      FRINT 215. TKIN
                                                                           C2325100
C
                                                                           (2325200
C
                                                                           C2325300
C
      COMPLTE INENTIAL ACCELERATIONS
                                                                           C2325400
      CO 8 1=1.3
                                                                          C2325500
    e TC+C(1.1) = DUMC(1.1)
                                                                           C2325600
      IF (NECU.EQ.1) GC TC 57C1
                                                                           C2325700
      CO 14 K=2.N90D
                                                                           C2325800
      CALL VECTOS (FCMC(1.K).RCMC(1.K).TEMI)
                                                                           C2325900
   14 CALL VECSUB(DOMC(1.K). TEN1.TCMC(1.K))
                                                                           (2326000
5001 CONTINUE
                                                                          C2326100
      CALL VECTUS (FCMC(1.1).FCMC(1.NB1).TEM1)
                                                                          (2326200
      CALL VECSUB(DOMC(1.NBI). TEMI. TUMC(1.NBI))
                                                                          (2326300
      W = 1
                                                                          (2326400
```

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CO 2C K=1.NH1
                                                                           02326500
      IF (K.EQ.1) GC TO 21
                                                                           C2326600
                                                                           (2326700
      > = >+3-FCUN(K-1)
  21 CO 22 I=1.3
                                                                           00H45FC1
  22 TENI(1) = 0
                                                                           C2326900
      MMIERM=N+2-PCON(K)
                                                                           C2327000
      IF (M.GT. MMTERM) GC TO 20
                                                                           C23271C0
      CO 23 MM=M.MMTERM
                                                                           02327200
      CALL SCLV(THADD(MM).GFC(1.MM).TEM2)
                                                                           C2327300
   23 CALL VECADD( TEM1 . TEM2 . TEM1)
                                                                           C2327401
   20 CALL VECADD(TEMI.TCMC(1.K).CERV(1.K))
                                                                           02327500
C
                                                                           02327600
                                                                           C2327700
c
      CO 5 K=1.NBUD
                                                                           02327800
      PRINT 204. K.(RUMC(1.K).1=1.3).(FCMC(1.K).1=1.3)
                                                                           C2 32 7900
   10 FRINT 237. (DERV([.K).[=1.3)
                                                                           (2328000
      FRINT 223. (ETC(1.K), I=1.3).(PHI(1.K), I=1.3)
                                                                           (2328100
      FRINT 235. (CAC(1.K).1=1.3).(CUC(1.K).1=1.3)
                                                                           C2328200
      FRINT 216. (POS([.K).[=1.3).(VEL([.K).[=1.3)
                                                                           00685553
      FRINT 2CE. ((XMC(1.J.K).J=1.3).(XIC(1.J.K).J=1.3).[=1.3)
                                                                           02328400
      FRINT 214. (HE(J.K).J=1.31.TK(K)
                                                                           C2328500
      FRINT 216. (LM(J.K).J=1.3)
                                                                           (2328600
    E CONTINUE
                                                                           02328700
      FRINT 2CE. (FCMC(I.NBI). I=1.3).(DERV(I.NBI). I=1.3)
                                                                           C2328800
      PRINT 223. (ETC(1.AB1).[=1.3).(PHI(1.Nb1).[=1.3)
                                                                           02528900
      PRINT 224. (CBC(1.C).[=1.3)
                                                                           12329000
                                                                           C2329100
     PRINT 221. ((XMC([.J.0).J=1.3).1=1.3)
      FRINT 213
                                                                           00262223
      IF (NAC.EC.O) GC TC 41
                                                                           02329300
      00 6 M=1.NMO
                                                                           C2329400
                                                                           02329500
      PRINT 21C. M.HMUN(N).N.CLN(N)
                                                                           00008553
    & CONTINUE
      FRINT 213
                                                                           (2329700
                                                                           02329800
   41 CONTINUE
      IF (NEUDS.EU. 0) GD TU 40
                                                                           02229900
                                                                           02330000
      CALL UNPACISET. NSET. SFLX)
                                                                           02333100
      WN = C
     CO 33 KK=1.NSET
                                                                           C2330200
      K = SET(NSET+1-KK)
                                                                           C2333300
     00 34 1=1.3
                                                                           (2330400
                                                                           C2330500
      EP(1) = C
                                                                           C2330600
      FQC(1) = 0
      FOCC(1) = 0
                                                                           C2330700
                                                                           C2333400
      CO 34 J=1.3
     EI(1.J) = 0
                                                                           02330900
      EIC(1.J) = 0
                                                                           C233100C
                                                                           (2331100
  34 CONTINUE
                                                                           02331200
      SFXMK = SFXM(K)
     CO JE N=1. SFXNK
                                                                           C2331300
                                                                           C2331400
      MN = MN+1
     AFMA = AFER+MN
                                                                           C2331500
                                                                           C2331600
      CALL SCLV(THA(NFMA).FLA(1.MA).TEM1)
      (ALL VECADD(EP.TEMI.EP)
                                                                           C2331700
      (ALL SCLV(THAD(NFWN).FLG(1.WN).TEM1)
                                                                           02331800
                                                                           C2331900
     CALL VECADU(FQD.TEN1.FGD)
                                                                           02332000
      CALL SCLE(THA(NFMN).FLE(1.1.NN).TEME)
                                                                           C2332100
      (ALL CYACD(EI, TEME, EI)
     CALL SCLC(THAD(NFMN).FLE(1.1.MN).TEMS)
                                                                           02232200
                                                                           C2332300
     CALL CYACLIE ID . TEME . EIC)
                                                                           C2332400
  35 CONTINUE
```

```
C233250C
    PRINT 226. (EP(1).1=1.3).(EFD(1.K).1=1.3)
    FRINT 22t. K. (FuD(1).1=1.3)
                                                                        C2332600
    PHINT 229. ((EI(I,J),J=1,3),(EID(I,J),J=1,3),I=1,3)
                                                                        C2332700
                                                                        02332800
    FRINT 230, (FLIRC(1.K).1=1.3),(FLCHC(1.K).1=1.3)
    FRINT 231. (DHM(1.K). [=1.3)
                                                                        C2332900
 33 CONTINUE
                                                                        C23330C0
    FRINT 213
                                                                        (2333100
 40 CONTINUE
                                                                        (2333200
   CC 9 I=1.NFER
                                                                        C2333300
  9 FRINT 22C, (1.THA(1).1.THAD(1).1.THADD(1).1.(UFC(J.1).J=1.3))
                                                                        C2333400
    NI = NFER+1
                                                                        C2313500
    N2 = NFER+MN
                                                                        02333600
    IF (MN.EG.O) RETURN
                                                                        C2 33 3 700
    CO 12 I=N1.N2
                                                                        C2333800
 12 FRINT 225. I. THA(1).1. THAD(1).1. THAD(1)
                                                                        02233900
200 FORMAT (' CENTER OF MASS = 1.3017.8./)
                                                                        02034000
201 FORMAT (/.JA. "HUJEY = ".3D17.d)
                                                                        C2334100
202 FORMAT (3x. HINERT = 1.3017.4)
                                                                        00248550
                                                                        C23343C0
203 FORMAT ("1 TIME = ".D15.E./)
204 FORMAT(/,3x, 'BODY ',12.4x, 'FCMC =',3D17.d.3x, 'FCMC =',3D17.8)
                                                                        (2334400
205 FORMAT (14x, 'CAC = '.3D17.8.3x. 'CBC = '.3D17.8)
                                                                        (2334500
206 FORMAT (14x, 'XMC = '.3D17.8.3X, 'XIC = '.3D17.8)
                                                                       (2334600
207 FURMAT (14x. 'ACC = 1.3017.8)
                                                                        C2334700
208 FORMAT (/.3x, 'URIGIN', 4x, 'FCMC = ', 3D17.d, 3x, 'ACC = ', 3D17.8)
                                                                       C233480C
205 FORMAT ( ANGULAR MOMENTLM = 1.020.0)
                                                                        (2334900
210 FORMAT (3x, 'HMCM(',12,') = ',017.8,10x, 'LLM(',12,') = ',017.8)
                                                                        02335000
211 FURMAT (25A, 3017.8)
                                                                        C2335100
212 FORMAT ( SYSTEM INEHTIA TENSOR = . . JO17.d)
                                                                        (2335200
213 FCRMAT ( * 1)
                                                                        C2335300
214 FORMAT(14x. Hd = '. 3D17.8.3x. TK = '.D17.8)
                                                                        C23354C0
ELE FORMAT (/. KINETIC ENERGY = 1.020.8)
                                                                        C2335500
216 FORMAT (14x, 'PCs = 1,3017.8.3x, VEL = 1,3017.8)
                                                                        C2335600
217 FORMAT (/. LINEAR MCMENTUR = 1.020.3)
                                                                        C233570C
-18 FORMAT (14x. ' LN = 1.3017.8)
                                                                        C2335800
215 FORMAT (7.3x. LduCY = 1.3017.4)
                                                                       C233590C
22C FORMAT (3x, 'THA(',12,') =',013.0,3x, 'THAD(',12,') =',013.6,3x, 'THAC2236000
   *(D(',12,') =',D13.6,3x.'GFC(',12,') =',3013.6)
                                                                        02136100
2.1 FORMAT (14x, *xMC = *.3017.8)
                                                                        002336200
222 FORMAT ( TOTAL SYSTEM MASS = . . D17.8./)
                                                                       (2336300
223 FURNAT (14A, 'ETC = '.3D17.8.3X, 'PHI = '.3D17.8)
                                                                       (2336400
224 FURMAT (14x. *C3C = *.3C17.8)
                                                                        02336500
225 FORMAT (3x. THA('.12.') = '.013.0.3x. THAD('.12.') = '.013.6.3x. THAC2336600
   . ED('.12.') = '. D13.c)
                                                                        C2336700
226 FORMAT (/,3x,'FLEXIBLE',3x,' CP = ',3017.8,3x,'EPP = ',3017.8)
                                                                       C233680C
226 FORMAT (34. BODY 1.12.4x. 60 4 1.3017.8)
                                                                       C2236900
225 FCRMAT (14x.' El = '.3017.8.3x.'EID = '.3017.0)
                                                                       C2337000
230 FURMAT (14x, FIR = 1,3017.8,3x, FCR = 1,3017.0)
                                                                        (2337100
231 FORMAT (14x. 'DHM = '.3017.8)
                                                                       C2237200
    RETURN
                                                                       (2337300
    ENC
                                                                       C2337400
```

```
LIFANY . LEATE . LXDY . LETA . LTGEQU .
                                                                        (2430500
                      LOFDOT . LOCT . LANGLE . LSETUP . LSIMO
                                                                        0.000000
C
                                                                         (2400700
     CIMENSICA D(1).C(1)
                                                                         02422300
     EIMENSION DD (33.33).CC(33)
C
      USED TO CHITAIN SOLUTION OF A SET OF SIMULTANEOUS LINEAR EQUATIONS (2401000
C
                       C+x = C
C
                                                                         C2401200
      DESCRIPTION OF PARAMETERS
C
             L = COEFFICIENT MATRIX STUNED CULUMN-MISE DESTRUYED DURINGC2401400
C
                CCMPUTATION
                                                                         C2471500
C
              N = NUMBER OF EGLATIONS
                                                                         C24016CC
             NO = DIMENSION OF ARRAYS D AND C IN THE CALLING SUBROLTINE (2401700
C
              C = VECTUR OF CHIGINAL CONSTANTS OF LENGTH N. THESE ARE C2401800
C
                  REPLACED BY THE SULUTION VECTUR
                                                                        C2421900
C
                                                                        (2402000
      COMMEN /LDEJUG/ LHUNGE . LTRNS1 . LVDIV . LEQUIV . LTHAN .
                                                                        00150453
                     LTHANV . LRATE . LXDY . LETA . LTORQU .
                                                                        02402200
                      LOFOCT . LECT . LANGLE . LIETUP . LING
                                                                        (24)2300
     FOLIVALENCE (LSING. LFQU)
                                                                        C243240C
      IF (LEGU) PRINT 107
                                                                        12432500
C
                                                                        C243260C
C
      TAKE ARRAY D FROM LIMENSION NUMBER AS DEFINED IN CALLING SUBFOLLTINE C2402700
0
        TE AN INNI ARRAY
      IJ = 0
                                                                         02402900
     00 14 J=1.N
                                                                        (2403000
      J3 = (J-1) .NC
                                                                        (24)3100
      CO 15 1=1.N
                                                                        C2403200
      1J = 1J + 1
                                                                        02423300
      C(1J) = C(1+J3)
                                                                        22433400
      IF (LEGU) DO(1.J) = D(1J)
                                                                        02403500
   15 CENTINUE
                                                                        C24236CC
      IF (LEGU) CC(J) = C(J)
                                                                        C2473700
   14 CONTINUE
                                                                        C2403800
C
                                                                        (2433900
C
      FORWARD SULUTION
                                                                        02404000
C
                                                                        C2404100
      10L = 3.00
                                                                        C2424200
      *5 = J
                                                                        02404300
      -J = -14
                                                                        22404400
      CO 65 J=1.N
                                                                        02414500
      .Y = J+1
                                                                        02404600
      1+A+LL = LL
                                                                        (2404700
     E1CA = 0.00
                                                                        C2404HOC
      1T = JJ-J
                                                                        C24C4900
      00 33 I=J.N
                                                                        C243500C
                                                                        (2405100
     SEARCH FLH MAXIMUM CCEFFICIENT IN COLUMN
                                                                        02405200
(
                                                                        (2475300
      II = IT+I
                                                                        C24754C0
      IF (DADS(ELGA) - CAES(C(13))) 21.33.35
                                                                        (2405500
   21 FICA = L(IJ)
                                                                        02405600
      IMAX = I
                                                                        C2405700
   33 CONTINUE
                                                                        (2405800
                                                                        02435900
C ... TEST FOR PIVOT LESS THAN TOLERANCE
                                                                        12436000
                                                                        C240610C
     IF (DAES(EIGA) - TCL) 35.35.40
                                                                        C2496200
  35 KS =1
                                                                        C2406300
     FRINT 103
                                                                        C2406400
```

```
STCP
                                                                            02436500
      FETUEN
                                                                            C2406600
                                                                            (2476700
      INTERCHANGE HOWS IF NECESSARY
C
                                                                            (2406800
c
                                                                            02426900
   40 II = J + N+(J-2)
                                                                            (2407000
      IT = IMAX - J
                                                                            02407100
      CO 50 K=J.N
                                                                            C2407200
      11 = 11 + N
                                                                            (2407300
      12 = 11 + 17
                                                                            C24C7400
      SAVE = C(II)
                                                                            C2407500
      C(11) = C(12)
                                                                            (2407600
      C(12) = SAVE
                                                                            C2407700
C
                                                                            C2407800
C
      CIVICE EQUATION BY LEADING COEFFICIENT
                                                                            (2437900
C
                                                                            C2478C00
   50 C(11) = C(11)/81GA
                                                                            (2408100
      SAVE = C(IMAX)
                                                                            02408200
      ((IMAX) = C(J)
                                                                            C24C8300
      C(J) = SAVE/BIGA
                                                                            C24084C0
                                                                            C2438500
c
      ELIMINATE NEXT VARIABLE
                                                                            C24C86C0
C
                                                                            C2408700
      IF(J-N) 55.70.55
                                                                            C240880C
   55 105 = N+(J-1)
                                                                            C2418900
      CO 65 IX=JY .N
                                                                            C2409000
      IXJ = IGS + IX
                                                                            (2409100
      IT = J - IX
                                                                            C2409200
      CO 60 JX = JY.N
                                                                            C24393C0
      1xJx = N+(Jx-1) + 1x
                                                                            (24)9400
      TI + XLXI = XL
                                                                            (2475500
   6C C(1XJX) = D(1XJX) -(D(1XJ)+C(JJX))
                                                                            C242960C
   65 ((1x) = ((1x) - (C(J)*C(1xJ))
                                                                            (2405700
                                                                            C2429800
C
      EACK SCLUTION
                                                                            C2409900
                                                                            C2410000
   7C AY = A-1
                                                                            (2410100
      IT = NON
                                                                            C2410200
      CO 8C J=1 -NY
                                                                            02410300
      IA = IT - J
                                                                            C241C400
      18 = N - J
                                                                            (2410500
      IC = N
                                                                            (2410600
      DO 8C K=1.J
                                                                            C2410700
      ((IB) = ((IB) - 0(IA)*C(IC)
                                                                            C2410800
      IA = IA-N
                                                                            C24109CC
   8C IC = IL-1
                                                                            C2411C00
C
                                                                            C2411100
•
                                                                            C2411200
      IF(.NOT. LEGU) GO TO 1000
                                                                            C241130C
      TESTI = C.DO
                                                                            C2411400
      CO 1 1=1.N
                                                                            C2411500
      TESTE . C.DO
                                                                            (2411600
     CO 2 J=1.N
                                                                            C2411700
    2 TEST2 = TEST2 + DC(1.J) +C(J)
                                                                            C2411800
      TESTE = TEST2 - CC(1)
                                                                            C2411900
     FRINT ICE. I.TEST2
                                                                            C2412000
      1EST1 = 1EST1 + TEST2++2
                                                                            C241210G
    1 CONTINUE
                                                                           C2412200
     TESTI = CSQRT(TESTI)
                                                                            C2412300
     FRINT ICS. TESTI
                                                                            C24124C0
```

```
12412600
  ICC FORMAT ( oDIE.5)
                                                                          (2412700
  103 FORMAT ( * MATRIX IS SINGULAR GARDAGE FULLOWS .)
                                                                          02412800
  104 FURMAT ( *
                 O('.14.') = XMN('.12.'.'.12.') = '.020.10)
 105 FORMAT ( *
                 .,
                                                                          C241 3000
  106 FORMAT (' C(',12,') = ',020.10)
  107 FORMAT ('1 SUBRULTINE SING ENTERED ')
                                                                          22413200
  108 FORMAT (' ERRCR IN ROW'.12." = '.017.8)
                                                                          C2413300
  105 FORMAT ( NURM OF ERRCR VECTUR = 1.017.8)
                                                                          (2413400
      FETUEN
                                                                          C2413500
      END
                                                                           C241 3600
C
                                                                           (2500000
     SUBRICUTINE KUNGE(T.H.Y.YC.N1.N2.TEM)
                                                                           (2500100
      IMFLICIT REAL+8(A-H.O-Z.1)
                                                                          02500200
      LCGICAL LEQU
                                                                          C2500300
     LOGICAL
                      LRUNGE . LTRNSI . LVDIV . LEQUIV . LTRAN .
                                                                          (2500400
                      LTRANV . LRATE . LXDY
                                                . LETA . LTOFQU .
                                                                          02530500
                                       . LANGLE . LSETUP . LSIMO
                      LOFDCT . LDCT
                                                                          (2500600
      COMMEN /LDEBUG/ LRINGE . LTRNS! , LVDIV . LEGGIV . LTRAN .
LTRANV . LRATE . LXDY . LETA . LTGRGU .
                                                                          (2500700
                                                                          (2500800
                      LCFDOT , LDCT , LANGLE , LSETUP , LSIMO
                                                                           C2500900
     EQUIVALENCE (LRUNGE, LEGU)
                                                                           02501000
      CIMENSICH Y(1) .YC(1) .TEM(2.1)
                                                                          (2501100
C
      ACCEFTS SYSTEM STATE AT TIME T
                                                                           02501200
C
      FETURNS SYSTEM STATE AT TIME TOH
                                                                           C2501300
      SYSTEM STATE Y(N)
C
                                                                           C2531400
C
      CERIVATIVE OF Y(N) IS YD(N)
                                                                          (2501500
c
     SUPRCUTINE DYN COMPUTES YD(N) AS REGULRED BY RUNGE KUTTA
                                                                          (2501600
C
     NUMBER OF STATE VARIABLES IS 41 + N2
                                                                          C2501700
C
      MI = NUMBER OF DYNAMIC ECUATIONS
                                                                           02501800
C
      N2 = NUMBER OF EQUATIONS FHOM TOHOUE
                                                                          02501900
      TEMPERARY STERAGE AREA TEM (2.N) NOT TO BE USED IN DYN
                                                                          (2502000
      SN + 14 = 4
                                                                          (2502100
      IF (LEGU)FRINT 202
      F(LEGU)FRINT 200. (1.Y(1).1.YD(1).1.TEM(1.1).1.TEM(2.1).1=1.N) C2502300
      K = C
                                                                           (2502400
      CO 1 1=1.N
                                                                           02532500
      TEN(1.1) = Y(1)
                                                                          02502600
    1 TEM(2.1) = YD(1)
                                                                           02502700
      CD = +/2
                                                                           C251280C
      A = CD
                                                                           C25029C0
   2 1 = 1 + CD
                                                                           C2503000
    3 CC 4 [=1.N
                                                                           02503100
    4 Y(1) = TEM(1.1)+A+YD(1)
                                                                           00510350
      IF (LEGU)PRINT 201. (I.Y(I).I.YO(I).I.TEM(I.I).I.TEM(2.I).I=1.N)
                                                                          02503300
      CALL DYN (Y.YD.NI)
                                                                          02593499
      IF (LEGU)PRINT 200. (1.Y(1).1.YD(1).1.TEM(1.1).1.TEM(2.1).1=1.N)
                                                                          02533500
      K=K+1
                                                                           02503600
     1F (K.EQ.3) GC TO 7
                                                                          C2503700
      CO 5 1=1.N
    5 TEM(2.1) = TEM(2.1) + 241C(1)
                                                                          00980350
      IF (K.EU.1) GO TO 3
                                                                          C25040C0
      A = +
                                                                          C2504100
     CO TC 2
                                                                          02504200
```

C2412500

100C CONTINUE

```
7 4 = 4/0
                                                                            C250430C
      CO 6 1=1.N
                                                                            C2504400
      TEM(2.1) = A*(TEM(2.1) + YD(1))
                                                                            C2504500
    6 Y(1) = TEM(1.1) + TEM(2.1)
                                                                            02504600
      IF (LEGU) FRINT 201, ([,Y(1),1,YD(1),1,TEM(1,1),1,TEM(2,1),1=1,N)
                                                                           C25047C0
      (ALL DYN(Y.YD.NI)
                                                                            02674800
      IF (LEJU) PRINT 200. (1.Y(1).1.YD(1).1.TEM(1.1).1.TEM(2.1).1=1.N) (2504900
  200 FORMAT (' IN RUNCE Y('.12.') = '.ula.s.' YC('.12.') = '.D18.8.' TC2505000
     *EM(1.'.12.') = '.C18.6.' TEM(2.'.12.') = '.D18.8)
                                                                            C2505100
  201 FORMAT (' DUT RUNGE Y('.12.') = '.015.d.' YD('.12.') = '.016.e.' 102505200
                                                                            C2505300
     *EM(1,',12,') = ',D18.8.' TE*(2,',12,') = ',D18.8)
  202 FORMAT (*1*)
                                                                            C2505400
      SE TUEN
                                                                            C25055CC
      ENC
                                                                            C250560C
C
                                                                            C2600000
      SLERCUTINE UNCAGE (SCG. SC. T. TUU)
                                                                            (2600100
      IMPLICIT HEAL+8(A-F.O-Z.1)
                                                                            (2600200
      INTECEM SCG. SC(1) .SCG1
                                                                            C26003C0
      CIMENSICK TUG(1)
                                                                            C2420400
       TEST TO SEE IF TIME TO LACAGE ANY DEGREE OF FREEDOM
C
                                                                            C2600500
        IF YES DU SO AND RENLMEEN SC ARRAY
C
                                                                            £2600600
      SCG1 = SCG
                                                                            (2630700
      CO 6 1=1.SCG1
                                                                            CZECCHOC
      IF (T.LT. TUG(SC(I))) GU TC 6
                                                                            00000953
      SCG = SCG-1
                                                                            C2601000
      FRINT 10C. SC(1).T.SCG
                                                                            00110952
      SC(1) = C
                                                                            C2601200
    E CONTINUE
                                                                            C2621300
      IF (SCC.EG. SCG1) HETURN
                                                                            (2(01400
      J=C
                                                                            02601500
      CC 7 1=1.5Cul
                                                                            C2601600
      IF (SC(1).EU.C) GO TO 7
                                                                            C2601700
      J= J+ 1
                                                                            02601800
      EC(J)=5((1)
                                                                            00010353
      IF (1.E4.J) GC TO 7
                                                                            (2602000
      SC(1) = C
                                                                            C243210C
    7 CONTINUE
                                                                            C2602200
                 MOTION ABOUT PREE VECTUR ".12." UNCAGED AT T =".E15.5.02602300
  100 FORMAT ( .
     . WOTION STILL CAGED ABOUT ".12." FREE VECTORS ")
      FE TUFN
                                                                            C2602500
      ENC
                                                                            02602600
      SUBRCUTINE COMPRE (>MN. THACC .N. SC .SCG .LG)
                                                                            C2692700
      IMPLICIT HEAL+B(A-F.O-2.1)
                                                                            C2602800
      CIMENSICK XMM(33.1).THACC(1)
                                                                            02602900
      INTEGER SCIII.SCG
                                                                            02623909
      LOGICAL LG(1)
                                                                            02603100
      SET LF LLGIC FLAGS
                                                                            C2603200
      AS = A + SCG
                                                                            000003300
      CO 7 1=1.N3
                                                                            C2603400
    7 LG(I) = .THUE.
                                                                            02603500
```

```
C2603600
   CO 8 1=1.SCG
 & LG(S((I)) = .FALSE.
                                                                                C2603700
   11 = 0
                                                                                (2603800
   CO 9 1=1.NS
                                                                                C2603900
   IF(.MOT.LG(1)) GO TO 9
                                                                                C2604000
                                                                                C2604100
   11 = 11+1
                                                                                C2604200
   THADC(II) = THADD(I)
                                                                                C2604300
   JJ = C
                                                                                C2604400
   CO 10 J=1.NS
                                                                                (2404500
   IF (.NJT.LG(J)) GO TO 10
   1+1C = CC
                                                                                C2604600
   (L.1) NMX = (LL.11) NMX
                                                                                C2604700
IC CCATINUE
                                                                                C2604800
                                                                                (2604900
 S CONTINUE
   RE TURN
                                                                                C2605000
                                                                                C2695100
   ENO
   SUBRCUTINE UNPRSITHADDINISCGILG)
                                                                                C2605200
   IMPLICIT REAL = E(A-H.O-Z.1)
                                                                                C2605300
   CIMENSICA THADC(1)
                                                                                C2+05400
   INTEGER SCG
                                                                                C2605500
   LOGICAL LG(1)
                                                                                C2605600
   12 = N
                                                                                C260570C
   NN = N+SCG
                                                                                (2625800
   CO 11 1=1.NN
                                                                                C2605900
   11 = NN+1-1
                                                                                C2606000
   IF (LC(11)) GO TO 12
                                                                                C2e06100
                                                                                C2606200
   THADE(III) = C.C
   CO TC 11
                                                                                C2626300
12 THACC(11) = THADD(12)
                                                                                C2606400
   12 = 12-1
                                                                                C269650C
11 CONTINUE
                                                                                C2606600
   SE TUEN
                                                                                22696700
   ENC
                                                                                C2606800
   SURRCUTINE COMPACISETINSETIES
                                                                                02606900
   IMPLICIT HEAL+8(A-H.O-Z.1)
                                                                                C2607000
                                                                                C2607100
   INTEGER SET (NSET) . A(24) . S . AB
  Z10 . Z2 . Z4 . Z8

Z10 . Z20 . Z40 . Z80

Z100 . Z200 . Z400 . Z800

Z1000 . Z200C . Z4000 . Z8000

Z10000 . Z200CC . Z40000 . Z80000

Z100000 . Z200CC . Z40000 . Z800000
                                                                                C2607200
                                                                               C2607300
                                                              .
                                                                              C24C7400
 .
                                                                               C2607500
 .
                                                                                C2607600
                                                                                C2607700
   CATA AB/ 21000000/
                                                                             C2607800
                                                                                C2607900
  TAKES THE SET OF INTEGERS STORED IN SET(NSET) AND COMPACTS
                                                                                C2e08C0C
   THEN INTO THE SINCLE CODED INTEGER BURD S. THE SET OF
                                                                               C26C8100
  INTECERS IN ARRAY SET MEST BE DISTINCT FROM EACH CTHER
                                                                               C2608200
   AND LIE ELTWEEN I AND 24 INCLUSIVE.
                                                                               C26 18300
```

C26C8400

C26C8500

SE NEET . Ab

IF (NEET . EU . O) GU TC 2

C

```
C2608600
     CO 1 K=1.NSET
    1 S= S + #(SET(K))
                                                                          C26C8700
      FETUEN
                                                                          C2608800
                                                                          C26089C0
    2 SET(1)=C
                                                                          €2€09000
      FETUEN
      ENC
                                                                          C2609100
      SUERCLTINE UNPAC(SET.NSET.S)
                                                                          C2699200
      IMFL ICIT REAL . (A-+ . 0- Z.1)
                                                                          C2609300
      INTECER SET(1).A(24).S.AB.15
                                                                          C2609400
                     . 22
                                               . 28
                                  . 24
     CATA A/ ZI
                                                                         C2609500
                                   . 240
                                               . 280
               Z10
                        . Z20
                                                                         C2609600
                                   . Z400
                       . Z200
                                               . 2800
               Z10C
                                                                         (2609700
                       . Z2C0C
                                   . 24000
                                               . Z8000
               21000
                                                                         (2609800
               210300
                        . Z20000
                                   . 240000
                                               . Z80000
                                                                         C2609900
               Z100000 . Z200000 . Z400000 . Z800000/
                                                                         (2610000
     DATA AD/ 21000000/
                                                                         C2610100
                                                                         C2610200
C
      CECOCES THE CODED BORD S TO OSTAIN THE ELEMENTS OF SETINSET)
C
                                                                          C2610300
C
      ELEMENTS OF SET RETURNED IN CECHEASING DROEM OF MAGNITUDE
                                                                         C2610400
         SET(1).GT.SET(2).GT. ... .GT. SET(NSET)
                                                                          C261 C500
      MSET = S/AH
                                                                          C261 C600
      IF (NSET.EQ.0) GO TO 5
                                                                          C261 C700
      I = C
                                                                          C261C800
      15= S-NSET AE
                                                                          (2610900
      KN=25
                                                                          C2611000
      CO 1 K=1.24
                                                                         C2611100
                                                                        . 02611200
      IF ( 15-A(KN-K)) 1.3.2
    2 1=1+1
                                                                         C2611300
      SET(1) = KN-K
                                                                          C2611400
      15 = TS-A(KN-K)
                                                                         C2611500
    I CONTINUE
                                                                          C2611600
    3 1=1+1
                                                                         C2611700
      SE 1(1)=KA-K
                                                                         C2611800
    4 SETUEN
                                                                         C2611900
    5 SET(1)=0
                                                                         02612000
      FETUEN
                                                                         C2612100
      ENC
                                                                         C2612200
      INTEGER FUNCTION KTO(N. ... K)
                                                                         C2612300
      IMPLICIT HEAL . 8(A-+.0-2.1)
                                                                         C2612400
      IF (K.GE.J) GC TO 1
                                                                         C2612500
      *TC=#+(N-1)+J+1-K+(K-1)/2
                                                                         C2612600
      GC TC 2
                                                                         C2612700
    1 KTC = J*(N-1) + K + 1 - J*(J-1)/2
                                                                         C2612800
    2 FETUEN
                                                                         C2612900
```

ENC

```
INTEGER FUNCTION KTI(N.J.K)
                                                                     C2613100
  INFLICIT REAL+8(A-F.O-Z.1)
                                                                     C2613200
  IF (K.GE.J) OC TO 1
                                                                    C2613300
  KT1=(K-1)*(N-1)+J-(K-1)*(K-2)/2
                                                                     C2e13400
  CO TC 2
                                                                    (2613500
1 KT1 = (J-1)*(N-1) + K - (J-1)*(J-2)/2
                                                                     C2613600
2 FETUEN
                                                                    C2613700
                                                                    C2613600
  ENC
                                       LOGICAL FUNCTION CTAIN(I.S.A)
                                                                    C2613900
  IMPLICIT REAL-8(A-F.O-Z.1)
                                                                    C2614000
  INTECER S(N)
                                                                    C2614100
                                                                    C2614200
     CTAIN = .TRUE. IF EOCY LAUEL | CONTAINED IN SET S(N)
= .FALSE. IF NOT
                                                                    CZE14300
                                                                    C2614400
 ELEMENTS IN SET (N) PLST BE PESITIVE NON-ZENE INTEGERS IN
                                                                    C2614500
     EITHER ASCENDING OR CECENDING URDER OF MAGNITUDE
                                                                    (2614600
                                                                     C2614700
  IF (N.EJ.C.CH.I.EQ.O) GC TC I
                                                                     C2614800
  A1 = A+1
                                                                    C2614900
  IF(S(A) - 5(1)) 2.2.3
                                                                     C26150C0
2 K = A
                                                                     C2615100
  L = -1
                                                                     C2615200
 GD TC 4
                                                                    C241530C
2 K = 1
                                                                    C2615400
                                                                    C2615500
 L = 1
4 IF(S(K)-1) 5.6.1
                                                                     C2615600
E K / K+L
                                                                    C2615700
 IF (K.EJ.C.ON.K.EJ.NI) GC TO 1
                                                                    C2615800
 GC TC 4
                                                                    02615900
1 CTAIR = .FALSE .
                                                                    02616000
  RETURN
                                                                    C2616100
e CTAIN = .TRUE.
                                                                    C2416200
  RE TUEN
                                                                    C2616300
  END
                                                                    C2416400
                                                                    C2720000
```

```
C
                                                                         C2700100
     SUBROUTINE VECTAR (VA.XMI.VAC)
      PERFCRMS THANSFORMATION OF COURSINATES FOR VECTORS
                                                                         (2700200
C
        XPT = MATRIX. TRANSFORMS VECTORS TO COMPUTING FRAME COCRCINATESC2700300
C
                                         FROM BODY LAMBA FIXED COUNCINATEZ700400
C
         VA = VECTOR INFLITED RELATIVE TO BODY LAMBA FIXED COURCINATES C2700500
C
        VAD = VECTOR CCMPCNEMIS COMPUTED RELATIVE TO COMPUTING FRAME
                                                                         C2700600
¢
                                                                         C2700700
                                                                         C2700800
C
      EQUATION SOLVED IS
C
                                                                         (2700900
                        VAD = (XMI) . VA
                                                                         C2701000
¢
C
                                                                         C2701100
      IMPLICIT REAL+8(A-+.0-Z.1)
                                                                         (2701200
                                                                         C2701300
      CIPERSICA VA(3).XPT(3.2).VAC(J)
                                                                         C2701400
      CC 1 1:1.3
                                                                         C27C1500
      >*C(1)=C
```

C

C

C

C

```
CO 1 ==1.3
    1 VAC(1)=VAD(1)+XMT(1.J)+VA(J)
                                                                           C2701700
      FETUEN
                                                                           (2701800
                                                                           C2701900
      ENC
      SUERCUTINE TENTRN(XI.XMT.XIC)
                                                                           C2702000
      TRANSFORM 3x3 TENSORS WITH CHECK FOR SYMMETRY
                                                                           (2702100
C
                                                                       C2702200
      IMPLICIT REAL . 8(A-F.C-Z.S)
      CIMENSICA XI (3.3) . XMT(3.3) . XIO(3.3)
                                                                           C2702300
      LCGICAL FLAG
                                                                           C2702400
      FLAG = . THUE .
                                                                           C2702500
             x1(1.2).EG.x1(2.1)
                                                                           02702600
      1F (
        .AND.>1(1.3).EQ.X1(2.1)
                                                                           C27C2700
         .#NO.X1(2.3).EQ.X1(3.2)) GU TO 2
                                                                           00850123
      FLAG : .FALSE.
                                                                           .02702900
    2 CO 1 1=1.3
                                                                           (2703000
      11 = 11
                                                                           C2703100
      IF(FLAG) GO TO 3
                                                                           C27C3200
                                                                           C2703300
      11 = 1
    3 CO 1 J=11.3
                                                                           C2703400
      x10(1.J) = 0
                                                                           C2703500
      CO 1 L=1.3
                                                                           C2703600
      CO 1 4:1.3
                                                                           C27037C0
      x((1.J) = x((1.J) + x)((1.L) * x((L.M) * xMT(J.M)
                                                                           (2703800
    I CONTINUE
                                                                           C2703900
      IF ( . NCT . FLAG ) RETURN
                                                                           C2704000
      xIC(2.1) = XID(1.2)
                                                                           (2704100
                                                                           C2724200
      AIC(2.1) = XID(1.2)
      x(C(2.2) = x(D(2.2)
                                                                           C2704300
      FE TUFN
                                                                           C2704400
      END
                                                                           C2704500
      SUBRCUTINE VECNEM (V)
                                                                           C2704600
      IMPLICIT REAL #8(A-F.O-Z.1)
                                                                           C2794700
      CIPENSIEN V(3)
                                                                           (2704800
       USEC TO NORMALIZE VECTORS TO UNITY
                                                                           C27C4900
C
      A = V(1)**2 + V(2)**2 + V(3)**2
                                                                           C2705000
      IF (A .NE .C) GC TO 1
                                                                           C2705100
      PRINT ICC
                                                                           C2705200
  100 FORMAT (* GIMBAL LOCK CONDITION, NORMALIZATION SKIPPED ERRORS PROCESCESSOO
     SEARLY FCLLOW ')
                                                                           C2705400
      FETUEN
                                                                           (2705500
    1 A = CSORT(A)
                                                                           C2705600
      CO 2 I=1.3
                                                                           (2705700
    2 V(1) = V(1)/A
                                                                           (2705800
      FE TUEN
                                                                           C27C5900
```

ENC

C2706000

```
(2706100
      SUERCUTINE MATMUL (A.d.C.N)
      IMPLICIT REAL+E(A-F.O-Z.1)
                                                                           (2706200
      CIPENSICH A(N.N) .E(N.N) .C(N.N)
                                                                           C2706300
C
      CCMPLTS THE STANDARD MATRIX PRODUCT OF THU NAN MATRICES
                                                                           C2706400
                    A+8 = C
                                                                           C2706500
C
      CC 1 1=1.N
                                                                           C27C6600
      CO 1 J=1.N
                                                                           C2706700
      C(I \cdot J) = C
                                                                           (2706800
      CO 2 L=1.N
                                                                           C27C6900
                                                                           02707000
    2 ((I.J) = C(I.J) + A(I.L)+d(L.J)
    1 CONTINUE
                                                                           02707100
      SE TUEN
                                                                           £2707200
      ENC
                                                                           (2707300
     SUERCUTINE TRNSPS
                         (XMI)
                                                                           C27C740C
      USED TO COMPUTE THE TRANSPOSE OF A 3X3 MATRIX
                                                                           C2707500
C
      IMPLICIT HEAL *8(A-+.0-2.1)
                                                                           C2707600
                                                                           C2707700
      CIMENSICH XMT(3,3).TEMF(3,3)
      00 1 1=1.3
                                                                           C2707800
                                                                           C27C790C
      CO 1 J=1.3
    1 TEMP(1.J) = XMT(1.J)
                                                                           (2708000
      CO 2 1=1.5
                                                                           (27CH100
     CO 2 J=1.3
                                                                           (2708200
    2 XMT(I.J) = TEMP(J.L)
                                                                           C27C8300
      RETURN.
                                                                           C2728400
      ENC
                                                                           (2708500
                                                                           (2708600
      SUBHCUTINE ROTIA.C.JA.THE)
      IMPLICIT HEAL+8(A-F.U-Z.1)
                                                                           C2708700
                                                                          C2708800
      CENERAL EULER ANGLE ROTATION MATHIX
C
      CIMENSICA TME(3.3).V(3).N(3)
                                                                          (2708900
      E = C/DAES(C)
                                                                          (2709000
      CO 24 N=1.3
                                                                          C2709100
      *(A) = 5
                                                                          (2709200
  24 V(N) = .CUO
                                                                          C2709300
                                                                          C2709400
      JJA = LABS(JA)
      ALL/ALPA = (ALL)
                                                                          C2709500
      *(JJ#) = 1.000
                                                                          C27C9600
      TME(1.1) = DSGRT(1.D0 - V(2)**2 - V(3)**2)**(1)
                                                                          C2725700
      THE(2.2) = DSQHT(1.00 - V(1)**2 - V(3)**2)**(2)
                                                                          C2709800
      TME(3.3) = DSORT(1.DC - V(1)**2 - V(2)**2)**(3)
                                                                          C2709900
                                                                          C2710000
      TME(1.2) = -V(3)
      TME(2.1) = V(3)
                                                                          C2710100
                                                                          C271 C200
      TME(1.3) = V(2)
      IME(2.1) = -v(2)
                                                                          C2710300
                                                                          C2710400
      1ME(2.3) = -V(1)
      TME(3.2) = V(1)
                                                                          C271C500
                                                                          C2710600
     RETURN.
                                                                          (271 0700
```

ENC

c	SUERCLTINE VECACD(V1, V2, S) ADCS VECTUR V1 TO V2 RESULT IN S IMPLICIT REAL+8(A-+.O-Z.1) CIMENSICN V1(3), V2(3), S(3) S(1) = V1(1) + V2(1) S(2) = V1(2) + V2(2) S(3) = V1(3) + V2(3) RETURN ENC	(2800000 C2800200 C2800300 C2800400 C2800500 C2800600 C2800700 C2800900
c	SUERCLTINE VECSUB(VI.V2.C) SUETRACTS VECTORS VI-V2=C IMPLICIT REAL+8(A-H.O-Z.1) CIMENSICN VI(3).V2(3).C(3) C(1) = V1(1) - V2(1) C(2) = V1(2) - V2(2) C(3) = V1(3) - V2(3) RETURN ENC	C280100C C2801100 C2801200 C2801300 C2801400 C2801600 C2801700 C2801800
c	SUERCUTINE SCLV(SC.V.P) SCAL ## VECTOR IMPLICIT REAL+8(A-F.C-2.1) CIMENSICN V(3).P(3) F(1) = SC*V(1) F(2) = SC*V(2) F(3) = SC*V(3) RETURN ENC	C2E01900 C2E02000 C2E02100 C2E02200 C2E02300 C2E02400 C2E02500 C2E02600 C2E02700
c	SUBRCLTINE VECDUT(VI.V2.C) VECTCR DCT PRUDUCT IMFLICIT REAL*8(A-+,0-2.1) DIVENSION VI(3).V2(3) D = VI(1)*V2(1) + VI(2)*V2(2) + VI(3)*V2(3) RETURN ENC	C2802800 C2802900 C2803000 C2803100 C2803200 C2803300 C2803400
c	SUER(UTINE VECROS (V1.V2.C) VECTOR CROSS PRODUCT C = V1 X V2 IMFLICIT REAL*8(A-H.O-Z.1) CIMENSIEN VI(3).V2(3).C(3) C(1) = V1(2)*V2(3)-V1(3)*V2(2)	C2803500 C2803600 C2803700 C2803800 C2803900

```
C(2) = V1(3) = V2(1) - V1(1) = V2(3)
                                                                             12804000
       C(3) = v1(1) *v2(2) - v1(2) *v2(1)
                                                                             C2804100
       SE TUEN
                                                                             (2604200
       ENC
                                                                             (2804300
       SUERCUTINE TRIPVP(VI.V2.V)
                                                                            C2804400
C
                                                                             C2804500
       CEMPLIES STANDARD VECTOR TRIPLE PRODUCT
C
                                                                             C2EC4600
C
                                                                             C2804700
C
                     V = LIX(VIXL2)
                                                                            C2#04800
C
                      = VI*(V1.V2) - V2*(V1.V1)
                                                                             C2804900
                                                                            C2805000
C
       IMPLICIT REAL . B(A-F.O-Z.S)
                                                                            C2805100
      CINENSICH V1(3).V2(3).V(3)
                                                                            C2E05200
       A = V1(1) * V2(1) + V1(2) * V2(2) + V1(3) * V2(3)
                                                                            C2805300
       E = V1(1) * V1(1) + V1(2) * V1(2) + V1(3) * V1(3)
                                                                             C2805400
       v(1) = v1(1)+A - v2(1)+B
                                                                            C2805500
       v(2) = v1(2)*A - v2(2)*E
                                                                             C2805600
       V(2) = V1(3) *A - V2(3) *E
                                                                            C2805700
       FE TUFN
                                                                             C2 e25800
                                                                            C2805900
      END
       SUBFICUTINE DYADD(CI.D2.D)
                                                                            C28C6000
      ADCS TOU DYADS
                                                                            C2806100
C
               C = D1 + C2
                                                                             00280820
                                                                            (2806300
       IMPLICIT HEAL+8(A-H.C-Z.1)
      CIMENSICA D1(3.3). D2(3.3). D(3.3)
                                                                            C2806400
                                                                            C2806500
      CO 1 1=1.3
      CO 1 J=1.3
                                                                            (2806600
    1 C(1.J) = D1(1.J) + D2(1.J)
                                                                            C2806700
       FE TUEN
                                                                            C2806800
      ENC
                                                                            C28C6900
      SUERCUTINE SCLC(A.C.T)
                                                                            C2807000
                                                                            C2807100
       IMPLICIT REAL+8(A-+.0-2.1)
      CIPERSICH D(3.3).7(3.3)
                                                                            C2607200
                                                                            C2007300
C
      WULTIPLY SCALAR BY A TENSOR
      T(1.1) = A+D(1.1)
                                                                            C2807400
                                                                            C2807500
      T(2.1) = A+D(2.1)
                                                                            C28C7600
      T(3.1) = A+D(3.1)
                                                                            (2807700
      T(1.2) = A+D(1.2)
                                                                            02807800
      (5.5) deA = (5.5)T
      T(3.2) = A+D(3.2)
                                                                            C2807900
                                                                            C2608000
      T(1.3) = A.D(1.3)
                                                                            00180353
      T(2.3) = A+D(2.3)
                                                                            C2808200
      T(2.2) = A+D(3.3)
      SE TUEN
                                                                            C2898300
                                                                            C26C8400
      ENC
```

```
SLERCUTINE DYDOTY(A.V.D)
                                                                           C2808500
      SCALAR OCT PRODUCT OF DYAD AND VECTOR
                                                                           C2808600
                D = A.V
                                                                           C2808700
c
      IMFLICIT HEAL+8(A-F.O-Z.4)
                                                                           C2808800
      CIPENSICH D(3).A(3.3).V(3)
                                                                           C2808900
      CO 1 1=1.3
                                                                           C2809000
      C(1) = C
                                                                           (2809100
      CO 1 J=1.3
                                                                           C2809200
    1 C(1) = C(1) + A(1.J)*V(J)
                                                                           C2809300
      SE TUEN
                                                                           C2609400
      ENC
                                                                           C28C9500
      SUERCUTINE VXDYOV(VI.DY.V)
                                                                           (2809600
C
      COMPLTES VECTOR X (DYAC . VECTOR)
                                                                           C2809700
                                                 .
              V = V1 X (CY . V1)
                                                                           C2809800
      IMPLICIT REAL+B(A-+.0-Z.1)
                                                                           C2E09900
      CIPENSICA VI(3). V2(3). V(3) . DY(3.3)
                                                                           C2810000
      CO 1 K=1.3
                                                                           C2810100
      12(K) = C.DO
                                                                           (281 0200
                                                                           C281 0300
      CO 1 J=1.3
    1 VS(K) = VS(K) + DY(K.J)*V1(J)
                                                                           C2810400
      V(1)= V1(2)+V2(3) - V1(3)+V2(2)
                                                                           C2810500
      v(2) = v1(3) +v2(1) - v1(1) + v2(3)
                                                                           C2610600
      v(2) = v1(1) +v2(2) - v1(2) +v2(1)
                                                                           C28107C0
      FETUEN
                                                                           (2610800
                                                                           C2610900
      END
      SUERCUTINE DYTOV (D.XI.X)
                                                                           C2611000
     USE TO TAKE SCALAR DCT PRODUCT OF TRANSPOSE OF
                                                                           C2811100
C
       TENSOR C WITH VECTOR XI
                                                                           C26112C0
      MEEDED SINCE TENSORS IN SYMPERIC MATRIX OF INERTIA TENSORS ARE IN (2811300
C
C
         NCN SYMMETRIC
                                                                           C2611400
      IMFLICIT HEAL . B(A-F.G-Z. 1)
                                                                           C2611500
      CIMENSICA 0(3.2). >1(3) . x(3)
                                                                           C2611600
      CO 1 1=1.3
                                                                           C2811700
      *(1) = C
                                                                           C26116C0
      CO 1 J=1.3
                                                                           C2811900
      >(1) = >(1) + D(J.1) *x1(-)
                                                                           C26120C0
    1 CONTINUE
                                                                           C2€12100
      FETUEN
                                                                           C281220C
      FNE
                                                                          C2812300
                                                        18 - 2 - 4
                                                                           (2612400
      SUERCUTINE VCCYOV(VI.DY.VZ.X)
                                                                           (2812500
C
      COMPLTES THE SCALAR TRIPLE PRODUCT
                   VECTOR . (DYAD . VECTUR)
                                                                           C261260C
C
                      VI.(DY. V2)
                                                                           C2812700
C
      IMPLICIT HEAL+B(A-h.C-Z.1)
                                                                           C2812800
                                                                           C2612900
      CIMENSILA VI(2).DY(3.3). V2(3).TEM(3)
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```
CC 1 K=1.3
                                                                           C2813C00
      TEM(K) = 0.00
                                                                           (2813100
      CO 1 J=1.3
                                                                           C2813200
    1 TEM(K) = TEM(K) + DY(K,J) + V2(J)
                                                                           C2813300
      ) = C
                                                                           (2613400
      CC 2 J=1.3
                                                                           C2813500
    z > = x + vl(J)*TEM(J)
                                                                           C281 36CO
      SE TUEN
                                                                           C2813700
      ENC
                                                                           C26138CO
      SUERCUTINE DYCF(V.C)
                                                                           C2E13900
      TRANSFORMS VECTOR VI INTO SKEN DYAD
                                                                           02814000
C
                                                                           C2814100
      IMPLICIT HEAL+8(A-F.O-Z.1)
      CIMENSILM V(3).C(3.3)
                                                                           (2814200
      C(1.1) = 0
                                                                           C2614300
      S(1.2) = V(3)
                                                                           C281440C
      C(1.3) = -v(2)
                                                                           (2814500
      C(2.1) = -V(3)
                                                                           00041957
      C(2.2) = 0
                                                                           C2814700
      C(2.3) = V(1)
                                                                           C2814800
      C(2.1) = V(2)
                                                                           C2814900
      C(3.2) = -V(1)
                                                                           C2815000
      C(3.3) = 0
                                                                           C2815100
      SETUEN.
                                                                           C2815200
      ENC
                                                                           C2615300
      SUERCUTINE SLEUP(VI.V2.XM.D)
                                                                          C2615400
      IMPLICIT REAL . E(A-F.O-Z.1)
                                                                          C2E15500
      CIMENSICA VI(3). V2(3). C(3.3)
                                                                          C2815600
      USED TO COMPUTE THE PSCECC INERTIA TENSOR
                                                                          C2E15700
       OF ECUY LANDA WITH RESPECT TO THE ORIGIN OF NEST K-1 AND
C
                                                                          C2815800
       THE HINGE POINT I-1 WHICH IS UN THE TUPOLOGICAL PATH FACM
C
                                                                          C2E15900
C
       BCDY I TO BCDY LANGA
                                                                           C2616000
         ELCCK & SUPPER GAMBA.SUE K-1.1-1 EQUATION 2-55 OF X-732-71-70 02816100
C
C
                    D = XM+((V1.V2)+1 - V2 V1)
                                                                          C2816200
C
                                                                          C2816300
        XN - SCALAR
C
                                                                          C2816400
        VI - VECTOR
                                                                          C2816500
C
         VE - VECTOR
                                                                          C2816600
C
C
         1 - LNIT CYAD
                                                                          C2816700
C
          . - SCALAR MULTIPLICATION
                                                                          C2816800
          . - VECTOR SCALAR MULTIFLICATION
                                                                          C26169C0
C
C
     ELANK - TENSON MULTIPLICATION
                                                                          22817000
      NOTE THAT IN GENERAL THE FSUEJU INERTIA TENSOR IS NON SYMMETRIC C2817100
C
C
                                                                          C2E17200
     C(1.1) = xM*(V1(2)*V2(2) + V1(3)*V2(3))
                                                                          C2817300
     C(1.2) =-XM+V2(1)+V1(2)
                                                                          C2617400
      C(1.3) =-XM+V2(1)+V1(3)
                                                                          C2E1 75CO
     C(2.1) =-xm+v2(2)+v1(1)
                                                                          C2817600
      ((2.2) = XM*(V2(1)*V1(1) + V2(3)*V1(3))
                                                                          C2E17700
                                                                          C2617600
     C(2.2) =-XM+V2(2)+V1(3)
     C(3.1) =-XM+V2(3)+V1(1)
                                                                          (2817900
```

```
CZBLBCCO
      [(3,2) =-XM#V2(3)+V1(2)
      ((3.3) = xM*(V2(1)*V1(1) + V2(2)*V1(2))
                                                                           (2618100
                                                                           C2818200
      SE TUEN
      ENC
                                                                           C2E18300
                                                                           C2500000
C
      SUBRELTINE GUTPUL (01.62.P)
                                                                           (2930100
      IMPLICIT REAL+8(A-H.O-Z.1)
                                                                           12500200
      CIMENSICH Q1(4).02(4).P(4)
                                                                           (2500300
      MULTIPLIES TWO QUATENIONS AND PUTS PRODUCT IN P
C
                                                                           C2500400
                                                                           (2900500
C
               P=01+02
      MERE
                                                                           C2900600
C
                                                                           C2500700
C
              . = GUATERNICH MULTIPLICATION
      40 = 41(1)
                                                                           (2500800
                                                                           02500900
      A1 = 01(2)
      A2 = C1(3)
                                                                           02901000
      43 = 01(4)
                                                                           C2901100
      E0 = G2(1)
                                                                           (2501200
      E1 = G2(2)
                                                                           (2501300
      E2 = 32(3)
                                                                           C2501400
      E3 = 02(4)
                                                                           C2901500
      F(1) = AC+d0 - A1+E1 - A2+B2 - A3+d3
                                                                           02901600
      F(2) = AC+d1 + A1+0 + A2+83 - A3+d2
                                                                           C2901700
      P(3) = A0+82 - A1+83 + A2+80 + A3+81
                                                                           (2901800
      F(4) = AC+B3 + A1+B2 - A2+B1 + A3+H0
                                                                           C2501900
      FETUEN
                                                                           C2502000
      ENC
                                                                           C2502100
      SUERCUTINE QUATUP (QF.THA.21)
                                                                           (2502200
      IMFLICIT REAL+8(A-+.C-Z.1)
                                                                           C2502300
      CIMENSICA OF (3).ZT(4)
                                                                           C2902400
      CCMPLIES ROTATION QUATERNICH FROM EIGENVECTOR OF AND ROTATION
C
                                                                           C2902500
        ANGLE THA. EQUATION A-11 OF X-732-71-89
                                                                           C2502600
      ZT(1) = CCOS(THA/2)
                                                                           C2502700
           = CSIN(THA/2)
                                                                           02902800
      5
      CO 1 J=2.4
                                                                           (2902900
    1 27(J) = GF(J-1)+5
                                                                           (2503000
      FETUEN
                                                                           02503100
                                                                           (2903200
      END
      SUERCUTINE TRANSDIGML. SLI
                                                                           C2903300
      IMPLICIT HEAL+B(A-F.O-2.1)
                                                                           C2903400
      CINENSILA GML(4). SL(3.3)
                                                                           (2903500
C
                                                                           (2903600
C
      MATRIX OPERATOR CONSTRUCTS THE QUATERNION TRANSFORMATION MATRIX SLC2503700
C
       FREM THE COMPONENTS OF THE QUATERNION UML(K)
                                                                         (2903800
C
      THE EULATION EVALUATE IS THE TRANSPOSE OF A-18 OF X-732-71-89
                                                                           02903900
.
       THAT IS. LET
                                                                           00040923
```

```
C
                   GML(K) = (E0.E1.E2.E3)
                                                                         (2904100
C
       THEN
                                                                         (2504200
-
                                                                         (2504300
C
  E C++2+E 1++2-E2++2-E3++2
                             2(EC*EJ+E1*E2)
                                                      2(E1*E3-E0*E2)
                                                                         (2504400
                         E0++2-E1++2+E2++2-E3++2 2(E2+E3+E0+E1)
     2(E1 +E2-E)+E3)
C
                                                                         C2974500
     2(E1+E3+E0+E2)
C
                              2(E2+E3-E0+E1)
                                                  E0**2-E1**2-E2**2*E3*(29C4600
c
                                                                         C250470C
C
                   SL(1.1)
                            SL(1.2)
                                       SL(1.3)
                                                                         C2504800
C
                 SL(2.1) SL(2.2) SL(2.3)
                                                                         (2504900
C
                   SL(3.1) SL(3.2) SL(3.3)
                                                                         (2505000
c
                                                                         02505100
C
                                                                         C2505200
     EOC = GML(1) +GML(1)
                                                                         (2905300
      EO1 = GML(1) +GML(2)
                                                                         C2575400
      E02 = GML(1) +GML(3)
                                                                         (2905500
      EC3 = GML(1) .GML(4)
                                                                         (2505600
      E11 = GPL(2) +GML(2)
                                                                         (2505700
      E12 = GPL(2) *GML(3)
                                                                         C2905800
      E13 = GPL(2) +GML(4)
                                                                         C2905900
      E22 = GML(3) +GML(3)
                                                                         C25060C0
      E23 = GML(3) +GML(4)
                                                                         (2506100
      E32 = GML(4) *GML(4)
                                                                         C2506200
      SL(1.1) = EOC + E11 - E22 - E33
                                                                        (2906300
      SL(1.2) = 20(EC3 + E12)
                                                                         (2906400
      SL(1.3) = 2+(E13 - E02)
                                                                         02506500
      SL(2.1) = 2*(E12 - E03)
                                                                         C29066C0
      SL (2.2) = E00 - E11 + E22 - E33
                                                                         C2906700
      SL(2.2) = 20(E23 + EC1)
                                                                         C2506800
      SL(3.1) = 20(E13 + E02)
                                                                         C290690C
      SL(3,2) = 20(E23 - E01)
                                                                         C2907000
      SL(3.3) = E00 - E11 - E22 + E33
                                                                         C2907100
     FETUEN
                                                                         (2507200
     END
                                                                         C2907300
```

. . .

APPENDIX B SUPPORT PROGRAMS FOR N-BOD2 FLEXIBLE BODY CAPABILITY

APPENDIX B

SUPPORT PROGRAMS FOR N-BOD2 FLEXIBLE BODY CAPABILITY

The flexible body options available in N-BOD2 require the user to obtain several resultant mode dependent parameters. These parameters will, for most applications, be computed from lumped parameter data obtained via the standard in-house finite element program. NASTRAN is the standard program at NASA/GSFC; however, other installations make use of other programs. Therefore, as a guide for the interested user, the following two programs are submitted and can either be used directly or be extensively modified to suit the situation existing at the particular computer installation that N-BOD2 will be applied.

The first program is actually the NASTRAN Executive Control Deck for a specially written DMAP program. This DMAP program will output all lumped parameter data necessary for the generation of the required N-BOD2 resultant mode dependent parameters. The program DISCOS referred to in the DMAP listing is another flexible body program being prepared by H. P. Frisch for release at GSFC. It requires similar data but in a completely different format.

This DMAP program is operational on the Macneal-Schwendler version 38 of NASTRAN and the Level 15.5 NASA version with one trivial change in the functional module GP4. (Built-in NASTRAN error messages will point out the change.)

The DMAP program was written so that, in addition to modes and frequencies (real), NASTRAN could be forced to output modal mass, stiffness, and damping matrices. Several print and punch options were also built in so that the user could see more clearly some of the resultant mass stiffness and damping matrices internally generated by NASTRAN. The interested user is referred to a NASTRAN Level 15 User's Manual (Reference 1) and Programmer's Manual (Reference 2) for a detailed description of the DMAP program. Basically it is a combination of rigid formats 3, 9, and 12.

```
10
         FRISCH. DISCOS N-HODZ NASTRAN
 DIAG
         14
TIME
        6000
  APP
         DMAP
         DISCOS AND N-BODZ DATA VIA NASTRAN $
  REGIN
 FILF
         GEOMI.GEDM2./GPL.EDEXIN.GPDT.CSTM.HGPDT.SIL/V.N.LUSET/ C.N.123/
 GP 1
         V.N.NOGPDT $
         LUSET.NOGPDT $
  SAVE
 CHKPNT GPL.EGEXIN.GPDT.CSTM.AGPDT.SIL
  PARAM //C.N.NOP/V.Y.PRTGD=1 $
 COND
        LBLIO. PRTGD $
  TARPT
            GPL.EDEXIN.GPDT.AGPDT.SIL// &
  TARPRT GPL//C.N.GPL $
  TABPRT GPDT//C.N.GPDT 5
  TABPRT BGPDT//C.N. HGPDT $
         LALIO $
  LAHFL
         USET.GM.GO.KAA.BAA.MAA.K4AA.PST.KFS.OP.EST/NOGPDT $
  PURGE
 CHKPNT USET.GM.GO.KAA.RAA.MAA.K4AA.PST.KFS.OP.EST
         GEOM2. EDEXIN/ECT $
  CHKPNT ECT $
         .ECT.EPT.AGPDT.SIL..CSTM/EST..GEI.ECPT.GPCT/V.N.LUSET/ C.N.
  TAI.
         123/V.N.NOSIMP/C.N.O/V.N.NOGENL/V.N.GENEL $
  SAVE
         NOGENL . NOS IMP . GENEL &
  CHKPNT EST.GEI.ECPI.GPCT $
         K4GG.GPST.DGPST.MGG.BGG. K4NN.K4FF.K4AA.MNN.MFF.MAA.HNN.BFF.
  PURGE
         HAA, KGGX/NOSIMP/ OGPST/GENEL $
 CHKPNT K4GG.GPST.OGPST.MGG.BGG.K4NN.K4FF.K4AA.MNN.MFF.MAA.BNN.BFF.
         RAA.KGGX
  SMAI
         CSTM.MPT.ECPT.GPCT. DIT/KGGX.K4GG.GPST/V.N.NDGENL/ V.N.NDK4GG$
  SAVE
         NOK4GG $
  CHKPNT KGGX.K4GG.GPST $
  PARAM
        //C.N.NOP/V.Y.PRTKG=-1 $
        LBL14.PRTKG $
 COND
 MATPRN KGGX .... // $
  LAREL LALI4 $
         KANN.K4GG.K4FF.K4AA/NOK4GG $
  CHKPNT KANN.K4GG.K4FF.K4AA
         CSTM.MPT.ECPT.GPCT.DIT/MGG.RGG/V.Y.WTMASS=1.0/V.N.NOMGG/ V.N.
  SMAZ
         NOBGG/V.Y.COUPMASS =- 1 $
  SAVE
         NOMGG.NORGG $
  CHKPNT MGG.BGG $
        //C.N.NOP/V.Y.PRTMG=-1 $
  PARAM
        LALII. PRTMG $
  COND
 MATPRN MGG....// $
 LAREL LBL11 $
  PARAM
        //C.N.NOP/V.Y.PRTMGD=1 $
         LALIS. PRIMGO $
 COND
 DIAGONAL MGG/MMG/C.Y.OPT=COLUMN/V.Y.POWER=1. $
 MATPRN MMG...// $
  LAREL
        LAL15 $
         BNN. BFF. BAA. RGG/NORGG $
  PURGE
  CHKPNT ANN. AFF. BAA. AGG. $
 CUND
         LBL1.GRDPNT S
         BGPDT.CSTM.EQEXIN.MGG/OGPMG/V.Y.GRDPNT=-1/V.Y.WTMASS &
  GPWG
 CHKPNT DGPWG &
  OFP
         DGPMG....//V.N.CARDNO $
  SAVE
         CARDNO $
  LAREL
        LBL1 $
        //C.N.MPY/V.N.NSKIP/C.N.O/C.N.O $
 PARAM
```

```
GP4
       CASECC.GEOM4.EDEXIN.SIL.GPDT.BGPDT.CSTM/RG..USET./V.N.LUSET/
       V.N.MPCF1/V.N.MPCF2/V.N.SINGLE/V.N.OMIT/V.N.REACT/V.N.NSKIP/
       V.N.REPEAT/V.N.NOSET/V.N.NOL/V.N.NOA/C.N.O $
SAVE
       MPCF1.SINGLE.OMIT.NOSET.REACT.MPCF2.NSKIP.REPEAT.NOL.NOA $
CHKPNT RG. USET $
       GM, GMD/MPCF1/GO, KOOB, LOO, UOO, MOOB, MOAB, GOD/OMIT/KFS, PST, QP/
PURGE
       SINGLE S
CHKPNT GM.GMD.GD.KOOB.LOD.UOO.MOOB.MOAB.GOD.KFS.PST.OP $
       KGGX.KNN/MPCF1/MGG.MNN/MPCF1/ BGG.BNN/MPCF1/K4GG.K4NN/MPCF1 $
FOUIV
CHKPNT KNN, MNN, BNN, K4NN, DGPST $
GPSP
       GPL.GPST.USET.SIL/DGPST $
OFP
       OGPST....//V.N.CARDNO $
SAVE
       CARDNO S
COND
       LBL2.MPCF1 $
MCE1
       USET.RG/GM $
       USET.GM.KGGX.MGG.RGG.K4GG/KNN.MNN.BNN.K4NN $
MCE2
CHKPNT GM.KNN.MNN.BNN.K4NN $
LARFI
       LBL2 $
       KNN.KFF/SINGLE/MNN.MFF/SINGLE/BNN.BFF/SINGLE/K4NN.K4FF/SINGLE $
VIUOS
CHKPNT KFF.MFF.BFF.K4FF
COND
       LBL3.SINGLE $
       USET.KNN, MNN. BNN. K4NN/KFF. KFS. . MFF. BFF. K4FF $
SCE1
LABEL
       LBL3 $
       KFF.KAA/OMIT/ MFF.MAA/OMIT/BFF.RAA/OMIT/K4FF.K4AA/OMIT $
FOUIV
CHKPNT KAA.MAA.BAA.K4AA $
COND
       LBL20.0MIT $
SMP1
       USET.KFF.,BFF.K4FF/GO.KAA,KOOB.LOO.UOO...,BAA.K4AA $
CHKPNT GO, KAA, KOOB, LOO, UOO, BAA, K4AA $
SMP2
       USET.GO.MFF/MAA $
CHKPNT MAA S
LABEL
       LBL20 $
PURGE
       KRR.KLR.DM.MLR.MR/REACT/CM/MPCF1/GO/DMIT/KFS/SINGLE/UG/NOSET $
COND
       LBL21.REACT &
RAMGI USET.KAA.MAA/KLL.KLR.KRR.MLL.MLR.MRR $
CHKPNT KLL.KLR.KRR.MLL.MLR.MRR $
RBMG2
      KLL/LLL.ULL 1
CHKPNT ULL.LLL $
RAMGS
      LLL.ULL.KLR.KRR/DM $
CHKPNT DM $
RAMG4
      DM.MLL.MLR.MRR/MR $
CHKPNT MR &
LABEL
       LBL21 $
DPD
       DYNAMICS.GPL.SIL.USET/GPLD.SILD.USETD.....EED.EDDYN/V.N.
       LUSET/V.N.LUSETD/V.N.NOTFL/V.N.NODLT/V.N.NOPSDL/V.N.NOFRL/V.N.
       NOMLFT/V.N.NOTRL/V.N.NOEED/C.N.123/V.N.NOUE $
SAVE
       NOEED . NOUE &
CHKPNT GPLD.SILD.USETD.EED.EQDYN $
COND
       ERROZ.NOEED
READ
       KAA, MAA, MR, DM, EED, USET, CASECC/LAMA, PHIA, MI, DEIGS/C, N, MDDES/ V.
       N. NEIGV S
SAVE
       NEIGVS
CHKPNT LAMA. PHIA. MI. DEIGS &
ADD
       MI./DI/C.N.(1.-10.0.0) $
DEP
       LAMA. DEIGS .... // V.N. CARDNO $
       FINIS.NEIGV $
COND
       USET.. PHIA... GO. GM.. KFS.. / PHIG. . QG/C.N. 1/C.N. REIG $
SDR 1
CHKPNT PHIG.OG
PARAM //C.N.NOP/V.Y.PRTMD=1 $
COND
       LBL12.PRTMD $
          PHIG .... // $
MATPRM
```

```
LABEL
         I RI 12 6
  SDR 2
         CASECC.CSTM.MPT.DIT.EQEXIN.SIL...HGPDT.LAMA.OG.PHIG.EST./.DQG1.
         OPHIG. DESI. DEFI. PPHIG/C. N. REIG $
 CHKPNT DOGI. OPHIG. DESI. DEFI. PPHIG $
 OFP
         OPHIG.OOGI.OEFI.OESI..//V.N.CARDNO $
         CARDNO S
  SAVE
         GO. GOD/NOUE/GM. GMD/NOUE $
  EQUIV
 CHKPNT GOD.GMD $
 MTRXIN CASECC.MATPOOL.EQDYN../K2PP.M2PP.B2PP/V.N.LUSETD/V.N.NOK2PP/V.
         N. NOM2PP/V.N.NOB2PP 1
         NOKZPP, NOMZPP, NORZPP &
  SAVE
 CHKPNT KZPP.MZPP.BZPP $
         //C.N.AND/V.N.KDEKA/V.N.NOUE/V.N.NOK2PP $
  PARAM
  PARAM
         //C.N.AND/V.N.MDEMA/V.N.NOUE/V.N.NOM2PP $
  PARAM
         //C.N.AND/V.N.KDEK2/V.N.NOGENL/V.N.NOSIMP &
  PURGE
         K2DD/NOK2PP/M2DD/NOM2PP/H2DD/NOH2PP $
  EQUIV
         M2PP.M2DD/NOA/82PP.82DD/NOA/K2PP.K2DD/NOA/MAA.MDD/MDEMA/ KAA.
         KDD/KDEKA
  GKAD
         USETD.GM.GO.KAA.BAA.MAA.K4AA.K2PP.M2PP.H2PP/KDO.BDD.MDD.GMD.
         GOD.K2DD.H2DD.B2DD/C.N.TRANRESP/C.N.DISP/C.N.DIRECT/C.Y.G=0.0/
         C.Y.W3=0.0/C.Y.W4=0.0/V.N.NOK2PP/V.N.NOM2PP/V.N.NOH2PP/ V.N.
         MPCF1/V.N.SINGLE/V.N.OMIT/V.N.NOUE/V.N.NOK4GG/V.N.NOHGG/ V.N.
         KDEK2/C.N.-1 $
  CHKPNT M2DD.B2DD.K2DD.MDD.KDD.BDD.GMD.GDD $
  GKAM
         USETD.PHIA.DI.LAMA.DIT.MDD.BDD.KDD.CASECC/MHH.BHH.KHH.
         PHIDH/V.N.NOUE/C.Y.LMODES=0/C.Y.LFRE0=0.0/ C.Y.HFRE0=0.0/C.N.
         1/C.N.1/C.N.1/V.N.NONCPU/V.N.FMODE &
 CHKPNT MHH, BHH, KHH, PHIDH
  PARAM
         //C.N.NOP/V.Y.PRTMM=1 5
 COND
         LBL13.PRTMM $
  MATPRN KHH, BHH, MHH, PHIDH, // S
        LBL13 5°
  LAREL
  PARAM //C.N.NOP/V.Y.PCHC =-1 5
 COND
         LBL6.PCHGD $
  TABPCH GPL.BGPDT...//C.N.GP/C.N.AG $
 LABEL
        LAL6 $
  PARAM //C.N.NOP/V.Y.PCHMG=-1 $
  COND
        LALT. PCHMG $
  OUTPUT3 MGG.,,,//C.N.O/C.Y.N1=MMG $
  LAREL
         LBL7 $
  PARAM //C.N.NOP/V.Y.PCHMD=-1 $
 COND
         LBLB.PCHMD $
  OUTPUT3 PHIG. . . . //C. N. O/C. Y. N1 = PHG $
  LABEL
  PARAM //C.N.NOP/V.Y.PCHMM=-1 $
 COND
         LBL9. PCHMM $
  OUTPUT3 KHH.BHH.MHH.,//C.N.O/C.Y.N1=KKH/C.Y.N2=HHH/C.Y.N3=MMH $
  LABEL
        LBL9 $
  JUMP
         FINISS
  LABEL
        ERROZ S
  PRTPARM //C.N.-2/C.N.MODES &
 LABEL FINIS &
  END
CEND
```

NASTRAN is extremely inflexible in allowing the user control over output data formatting. Consequently, a preprocessor program must be available to read the NASTRAN generated data. The next program is designed to not only read the data but also to process the data and compute the input data required by both N-BOD2 and DISCOS in respectively acceptable format.

For N-BOD2 users, the resultant mode dependent parameters are outputted on the line printer and annotated with the same acronyms used in the coding of the read data statements in subroutine INOPT.

```
C
C
      DISCOS. N-BOD2 PREPROCESSOR OF NASTRAN GENERATED DATA
C
C
C
         PURPOSE:
C
                 1) READ ONE OR MORE NASTRAN GENERATED TAPES
                  2) WRITE ONE INPUT TAPE FOR DISCOS PROGRAM
C
C
                      CONTAINING FLEXIBLE BODY DATA FOR ALL
C
                      FLEXIBLE BODIES IN SIMULATION
C
                  3) COMPUTE RESULTANT MODE DEPENDENT PARAMETERS
C
                      FOR GSEC MULTI-FLEXIBLE BODY PROGRAM
                      N-BOD2. THIS SECTION OF NO INTEREST TO
C
C
                      DISCOS USERS
C
C
C
         DEFINITIONS:
C
C
      DATA SET 1 = SCRATCH FILE USED TO PROCESS NASTRAN DATA
C
C
      DATA SET 2 = DISCOS INPUT TAPE (THE OUTPUT TAPE OF THIS PROGRAM)
         THE CARD OUTPUT OF THIS PROGRAM ASSUMES THAT DATA SET 14 IN
C
C
         DISCOS WILL BE RESERVED FOR THE FLEXIBLE BODY DATA
C
C
      DATA SET 3 = SCRATCH FILE USED TO REDUCE CORE REDUIREMENTS
0
C
      DATA SET 11 = LOCATION IN SYSTEM OF NASTRAN TAPE ASSOCIATED WITH
C.
                     THE FLEXIBLE BODY IN DISCOS HAVING LOWEST MAGNITUDE
C
                     INTEGER LAREL
C
C
      DATA SET 12 = LOCATION IN SYSTEM OF NASTRAN TAPE ASSOCIATED WITH
C
                     THE NEXT FLEXIBLE HODY IN THE DISCOS MODEL
C
C
C
                     PROGRAM DIMENSIONED FOR A MAXIMUM OF 6 NASTRAN TAPES
C
           ETC.
C
      IMPLICIT REAL ** (A-H.O-Z)
C
      DATA IDL/145/
      DATA ISTR. IALK/1H*.1H /
                             / AHGPL . AHRGPD . 4HMGG /
      DATA IGPL. INGP. IMGG
```

```
DATA ID. IT. 11/1HD. 1HT. 1H1/
      DATA IR. IE. IS/1HR. 1HE. 1HS/
C
      INTEGER
               INPT(80). IGRID(500). IA(20). IB(20).
               ICOT(5). IY(4)
      INTEGER MSAVE(100) . MSTOTL . HINGE
C
      REAL #8
               X(500).
                         Y(500).
                                  7 (500) .
               INERTA(6,6,500).
                                   PHI(6,500,12).
                                    AHH(12.12).
     .
               KHH(12,12),
                                    XX(4).
               MHH(12,12),
                                                    XY(4)
C
      REAL *8 AMD(500.72)
C
      COMMON /WORK/ AMD
C
      EQUIVALENCE (AMD(1.1).PHI(1.1.1))
      EQUIVALENCE (AMD(1.1).X(1))
      EQUIVALENCE (AMD(1.2),Y(1))
      EQUIVALENCE (AMD(1.3).Z(1))
      EQUIVALENCE (AMD(1.4).INERTA(1.1.1))
C
      LOGICAL LECHO, LPUNCH, LCHECK, LNAST
      LOGICAL LESTET
C
0
  100 FORMAT (15.3L5.215.L5)
  101 FORMAT (444.718.244)
  102 FORMAT (244.818)
  103 FORMAT (444.518.E16.9)
  104 FORMAT (244,2E16.9,116,E16.9)
  105 FORMAT (244.2E16.9)
  106 FORMAT (110)
  108 FORMAT (444.18.2116.E16.8)
  109 FORMAT (10E13.5)
  110 FORMAT (6E15.5)
  111 FORMAT (1215)
  112 FORMAT ('1'.15.3L5.215.L5)
  113 FORMAT (1x.2015)
  114 FORMAT (*1*,5x,****** MODAL DATA SELECTED FROM NASTRAN INPUT TAK
     *E'.14. FOR PROCESSING *******,//)
  115 FORMAT (12x, 'MODE'. 14, ' LISTED HELOW IS MODE'. 14, ' ON THE NASTRAN
     *DATA TAPE 1)
  200 FORMAT ( * NJOINT = *.15. * NUMBER OF GRID POINT LOCATIONS TO HE REAL
     * = 1.15. THESE SHOULD HE EDUAL 1
  201 FORMAT (
                              GRID POINT
                    NUMBER
                                            X-LOCATION
                                                            Y-LOCATION
     # Z-LOCATION ")
  202 FORMAT (6x.15.7x.15.2x.3E15.5)
  300 FORMAT (ROAL)
  302 FORMAT (444.18.2116.E16.8.244)
  303 FORMAT (244.4E16.8.244)
  400 FORMAT (2X.8041)
  500 FORMAT ( * ANDMOLOUS EOF MARK ON TAPE. LISTING FOLLOWS *)
  501 FORMAT (/. INTERNAL GRID POINT .. IS. EXTERNAL GRID POINT .. IS.
     *N THE NASTRAN BULK DATA DECK')
  502 FORMAT ( ' X.Y. 7 COORDINATES')
  503 FORMAT (6E20.10)
  504 FORMAT ( LUMPED INERTIA MATRIX!)
  505 FORMAT ( PHI (6 MODAL COMPONENTS FOR EACH SELECTED MODE) )
```

```
506 FORMAT (//. KHH 1)
   507 FORMAT ( 11,5x, 1 ****** LUMPED PARAMETER AND MODAL DATA TO BE PROCE
      *SSED FOR DISCOS AND N-ROD2 INPUT DATA *******,///)
   508 FORMAT (//. BHH 1)
   509 FORMAT (//. MHH 1)
   510 FORMAT (////)
   511 FORMAT (2x. 'EXIT DECODE '.4(18.816.8))
   512 FORMAT (2X, 'ENTER DECODE', 218, 4E16.8)
   600 FORMAT (15.3E20.8)
C
C
C
                     READ TWO INPUT CARDS PER NASTRAN TAPE
C
                        NTAPE = DATA SET WHERE TAPE IS TO
C
                                RE FOUND NTAPE=11.12....
C
                       LECHO = .TRUE. PRINT ECHO OF PROCESSED DATA
C
                              = .FALSE. PRINT ONLY IF ERROR FOUND ON TAPE
C
                       LPUNCH = . THUE. PUNCH PLOT DATA
C
                               = .FALSE. DON'T
C
                       LCHECK = .TRUE. PRINT DATA IN/OUT OF DECODE
C
                               = .FALSE. DON'T
C
                       HINGE = GRID POINT NUMBER OF HINGE POINT AS
C
                               DEFINED BY USER IN NASTRAN BULK DATA
                       MSTOTL = TOTAL NUMBER OF FLEXIBLE RODY MODES TO
C
C
                                 PROCESS FOR DISCOS AND N-HODE DATA
C
                       LNAST = .TRUE. PRINT NASTRAN DATA INPUT
C
                               .FALSE. DON'T
C
                       MSAVE = MODE SAVE ARRAY
C
                                  MSAVE(K) = 0 SKIP MODE K DATA
C
                                             K PROCESS MODE K DATA
C
      REWIND 2
    1 CONTINUE
      READ(5.100.END=4) NTAPE.LECHO.LPHINCH.LCHECK.HINGE.MSTOTL.LHAST
      WRITE(6.112)
                        NTAPE . LECHO . L PUNCH . L CHECK . HINGE . MSTUTI . L WAST
      READ(5.111) ([A([).[=1.MSTOTE)
      DO 11 1=1.100
   11 \text{ MSAVE(I)} = 0
      DO 12 I=1.MSTOTE
   12 MSAVE([A(1)) = [
      WRITE(6.113) MSAVE
      REWIND NTAPE
C
                          LASTAT = . FALSE. NO RESTART CARDS OF NIAPE
                                            METAKT CAPOS ON KTAPE
                                 = .TRUE.
      ICNTRS = 0
      LRSTRT = .FALSE.
    9 READ (NTAPE.300.END=H) INPT
      IFILMAST) WRITE(6.400) INPT
      CHECK FOR RESTART CARDS
     "IF(IR.NE.INPT(1)) GO TO 9
      IF(IE.NE.INPT(2)) GO TO 9
      IF(IS.NE.INPT(3)) GO TO 9
      IF(IT.NE.INPT(4)) GO TO 9
         COME HERE FOR RESTART CARDS. COUNT THEM AND SET FLAG
C
      LRSTRT = .TRUE.
      ICNTRS = ICNTRS+1
   13 READ (NTAPE.300.END=R) INPT
      IS(LNAST) WRITE(6.400) INPT
      IF(ID.EO.INPT(1).AND.IT.EO.INPT(2).AND.II.EO.INPT(3)) FO TO 9
      ICNTRS = ICNTRS+1
      GO TO 13
```

```
R CONTINUE
      REWIND NTAPE
      REWIND 1
      REWIND 3
      ICNT = 0
      IBLK = 0
      00 7 1=1.5
    7 \text{ ICOI(I)} = 0
C
C
               READ ALL DTI CARDS FROM NASTRAN TAPE NTAPE TO OHTAIN
C
                    1) GRID POINT NUMBERING SEQUENCE SET UP MY NASTRAN
C
                    2) GRID POINT LOCATIONS
C
C
           **** NOTE ****
C
C
               NASTRAN WILL RENUMBER GRID POINTS DEFINED BY USER
C
               INTO A SEQUENCIAL SET. THIS IS USED FOR INTERNAL NASTRAN
C
               COMPUTATION AND WILL BE USED BY DISCOS
C
C
      SKIP RESTART CARDS IN FRONT OF GOOD DATA
      IF(.NOT.LRSTRT) GO TO 2
      DO 14 1=1.1CNTRS
   14 READ (NTAPE, 300, END=3) INPT
    2 READ (NTAPE,101,END=3) ([A([),[=1,4),([A([),[=1,7),([A([),[=5,6)
C
          CHECK . FOR TABLE HEADING
      IF(1A(3).EQ. IGPL) GO TO 50
      IF(1A(3).EQ.18GP) GO TO 60
      IF(1A(3).EQ. IMGG) GO TO 70
      GO TO 2
C
       ERROR ON TAPE
C
    3 CONTINUE
      WRITE(6.500)
    6 REWIND NTAPE
    5 READ (NTAPE.300.END=4) INPT
      WRITE(6,400) INPT
      GO TO 5
    4 STOP
C
                 COME HERE TO PROCESS GPL TABLE DATA
   50 CONTINUE
      ICNT = ICNT + 1
      IF(ICNT.NE.1) GO TO 51
      NJ01NT = 18(2)
C
                               NJOINT = NUMBER OF GRID POINTS IN MODEL
      GO TO 2
   51 IF(ICNT.NE.2)GO TO 52
      DO 53 J=1.6
   53 IGRID(J) = IB(J+1)
      NC . (NJOINT-6)/8
      DO 54 J=1.NC
      JJ = 7 + 8*(J-1)
      JJ7 = JJ+7
   54 READ(NTAPE, 102) ([A([),[=1,2),([GRID(]),[=JJ,JJ7)
      JJ = 6 + B+NC
      JJ1 = JJ+1
      IF(JJ.EO.NJOINT) GO TO 2
      READ(NTAPE, 102) (IA(I), I=1,2), (IGRID(I), I=JJ1, NJD[NT)
      GO TO 2
C
                               IGRID(I) #USER DEFINED GRID POINT NUMBER
```

```
C
                                           WHICH NASTRAN HAS RELABLED TO
C
                                           HE INTERNAL NUMBER I
   52 ICNT = 0
      NC = (NJOINT-3)/4
       IF(NJNINT.E0.4#NC+3) GO TO 16
      NC = NC + 1
   16 DO 15 I=1.NC
   15 READ (NTAPE. 300) INPT
      GO TO 2
C
C
C
                  COME HERE TO PROCESS HGPDT CARDS
   60 CONTINUE
      IF(IR(2).EQ.NJOINT) GO TO 61
C
      FRROR
      WRITE(6.200) NJOINT. 18(2)
      GO TO 6
   61 READ (NTAPE. 300) INPT
      READ (NTAPE.103) ([A([).[=].4).([H([).[=].5).x([)
      TMIDLM.S=L SA OO
   62 RFAD (NTAPE,104) ([A([],[=],2),Y(J-]),Z(J-]),[H([],X(J)
      J = NJOINT
      READ (NTAPE.105) ([A([].[=1.2].Y(J).Z(J)
      GO TO 2
C
          SAVE LOCATION DATA. WHITE IT ON TAPE 3 AFTER INERTIA DATA
C
C
                 X(J) = X-CHORDINATE OF GRID POINT IGRID(J)
                 Y(J) = Y-COORDINATE OF GRID POINT IGRID(J)
C
                 Z(J) = Z-COORDINATE OF GRID POINT IGKID(J)
C
C
C
                     COME HERE TO PROCESS ALL DMI CARDS
C
          STEP 1:
C
                  COUNT CARDS IN EACH GROUP
C
                  ASCERTAIN FORMAT OF FACH CARD
C
                  REWRITE ON SCRATCH FILE ALL CARDS
C
                   PRECEEDED BY THEIR FORMAT CODE
C
         STEP 2:
C
                  REWIND SCHATCH FILE
C
                  READ CAKDS OFF SCRATCH FILE WITH KNOWN FORMAT
C
                  LOAD ALL ARRAYS. SKIPPING ALL UNWANTED MODES
   70 CONTINUE
      REWIND 1
      IFORM = 301
      WRITE(1.10A) IFORM
      WRITE(1.101) ([A(]),[=1.4).([H(]),[=].7).([A(]),[=5.6]
      IRLK = 1
      ICOT(IALK) = 1
      IF(IB(2).NE.6.OR.IB(6).NE.IB(7).OR.IH(6).NE.NJOINT*6) GO TO 71
      DO 76 I=1.NJOINT
      DO 76 J1=1.6
      DO 76 JZ=1.6
   76 INERTA(J1.J2.1) =0.0
      GO TO 72
   71 CONTINUE
      ERROR
C
      WRITE(6.101) ([A(]).[=1.4).([R(]).[=1.7).([A(]).]=5.6)
      GO TO 6
   72 READ(NTAPE.300.END=80) INPT
      IF(INPT(4).NE.ISTR) GO TO 73
```

```
ICOT(IBLK) = ICOT(IBLK) + 1
      IFORM = 302
      GO TO 74
   73 IF(INPT(1).EQ.ISTR) GO TO 75
C
                END OF DATA BLOCK IBLK
C
         CHECK FOR 'END OF CHECKPOINT DICTIONARY'
      IF(INPT(1).EO.IDL) GO TO 72
      IBLK = IBLK + 1
      ICOT(IRLK) = ICOT(IRLK) + 1
      IFORM = 301
      GO TO 74
   75 CALL INTERP(INPT. IFORM)
      ICOT(IBLK) = ICOT(IBLK) + 1
   74 WRITE(1,106) IFORM
      WRITE(1.300) INPT
      GO TO 72
   80 END FILE 1
C
                     ALL DMI CARDS READ, FORMAT DEDUCED AND
r
                     REWRITTEN ON SCRATCH FILE 1
C
      FORMAT CODES:
             301 = FORMAT (444.718.244)
C
             302 = FORMAT (4A4, 18, 2116, E16.8, 2A4)
C
             303 = FORMAT (244,4E16.8.7A4)
C
             304 = FORMAT (244.3E16.8.116.244)
C
             305 = FORMAT (244.2E16.8.116.E16.8.2A4)
(
             300 = FORMAT (244.E16.8,116.2E16.8,244)
C
             307 = FORMAT (244.E16.8.116.E16.8.116.244)
0
             308 = FORMAT (244, 116.8, 3E16.8, 244)
C
             309 = FORMAT (244,116.8,2E16.8,116.8,2A4)
Ċ.
             310 = FORMAT (2A4.116.E16.8.116.E16.8.2A4)
C
0
                          START TO PROCESS OM! CAKOS
      REWIND 1
      IF(IRLK.LE.5) GO TO 20
          ERROR TALK MUST BE LESS THAN OR FOLIAL TO 5
   81 REWIND 1
   83 RFAD (1.300.END=90) INPT
      WRITE(6.400) INPT
      GO TO 83
   90 STOP
   20 CONTINUE
      DO 22 IBK=1. IBLK
      ICBLK = ICOT(TRK)
      DO 21 JJ =1.1CBLK
      1F(JJ.NE.1) GO TO 23
C
           READ FIRST CARD OF DATA BLOCK
      READ (1.106) IFORM
      READ (1.101) ([A(]),[=1,4),([A(]),[=],7),([A(]),[=5,6)
      IF( IBK . NE . 1) GO TO 40
C
                    INERTIA MATRIX
C
      IF(IB(2).NE.6.OR.IB(6).NE.IB(7).OR.IB(6).NE.NJO[NI*6) GO TO 81
            SO FAR SO GOOD
      GO TO 21
   40 IFIIRK . NE . 21 GD TO 41
                    MODE SHAPES
C
      IF ( B(6). NE. 6 NJOINT) DO TO 91
```

```
NMODES = IR(7)
C
                                NMODES = NUMBER OF MODES
C
                                MSTOTL = NUMBER OF MODES TO PROCESS
       DO 42 11=1.6
      DO 42 12=1.NJOINT
       DO 42 13=1.MSTOTL
   42 \text{ PHI}(11,12,13) = 0.0
       GO TO 21
C
C
               MODAL MASS, STIFFNESS AND DAMPING MATRICES
   41 IF(IB(6).NE.IB(7).OR.IB(7).NE.NMODES) GO TO 71
      DO 43 !1=1.MSTOTL
      DO 43 12=1.MSTOTL
       IF(18K.NE.3) GO TO 44
      KHH(11.12) = 0.0
      GO TO 43
   44 IF( IHK . NE . 4) GO TO 45
      RHH(11.12) = 0.0
      GO TO 43
   45 MHH(11.12) = 0.0
   43 CONTINUE
      GO TO 21
C
                    READ IN DATA CARDS
   23 CONTINUE
      READ (1.106) IFORM
      IF(IFORM.NE.302) GO TO 24
      READ (1.302) ([A([).[=1.4).[R([),NNR.NNC.XX([).([A([),[=5.6)
      NSR = MSAVE(NNR)
      NSC = MSAVE(NNC)
      IF(IBK.NE.1) GO TO 25
      N1T = (NNC-1)/6 + 1
      N2T = (NNR-1)/6 + 1
      1F(N1T.EQ.N2T) GO TO 26
C
       FRROR
      WRITE(6,302) ([A[]),[=],4),[A(]),NNR,NNC,XX([]),([A(]),[=5,6)
      GO TO AL
   26 NT = N1T
      NC = MOD(NNC-1.6) + 1
      NR = MOD(NNR-1.6) + 1
      INERTAINE.NC.NT) = XX(1)
      GO TO 21
   25 IF(IBK.NE.2) GO TO 27
      NT = (NNC-1)/6 + 1
      NE = MOD(NNC-1.6) + 1
      IF(NSR.EQ.0) GO TO 21
      PHI(NE.NT.NSR) = XX(1)
      GO TO 21
   27 IF( IRK.NE. 3) GO TO 2H
      IF(NSR.EO.O.OR.NSC.EU.O) GO TO 21
      KHH(NSR.NSC) = XX(1)
      GO TO 21
   28 IF( 18K.NE.4) GO TO 29
      IFINSR.EQ.O.DR.NSC.EU.DI GO TO 21
      BHHINSR.NSC1 = XX(1)
     GO 10 21
  29 CONTINUE
      IFINSR.EQ.O.OR.NSC.EQ.OI GO TO 21
     MHH(NSR.NSC) = XX(1)
     60 10 21
```

```
C
   24 CONTINUE
C
          FORMAT 4E16.8 FOR XX WILL READ INTEGER I WHICH IS RIGHT
C
          JUSTIFIED AS 1 # 1.0E-OR
C
          THIS IS EASILY UNDONE IN DECODE
      READ (1.303) ([\Delta(1), i=1,2), (XX(1), i=1,4), ([\Delta(1), i=3,4)
      IF(LCHECK) WRITE (6.512) IFORM.NNC.(XX(I). I=1.4)
      CALL DECODE(IFORM, XX, NNC, XY, IY, NY)
      IF(LCHECK) WRITE (6.511) (IY(1).XY(1).I=1.NY)
      DO 30 I=1.NY
      IF(IBK.NE.1) GO TO 31
      NC = MOD(IY(I)-1.6) + 1
      INERTA(NR,NC,NT) = XY(1)
      GO TO 30
   31 IF(18K.NE.2) GO TO 32
      NT = (1Y(1)-1)/6 + 1
      NE = MOD(IY(I)-1.6) + 1
      IF(NSR.EQ.0) GO TO 30
      PHI(NE,NT,NSR) = XY(I)
      GO TO 30
   32 IF(IBK.NE.3) GO TO 33
      NSC = MSAVE(IY(1))
      IFINSR.EQ.O.OR.NSC.EQ.O) GO TO 30
      KHH(NSR.NSC) = XY(1)
      Gn Tn 30
   33 IF(18K.NE.4) GO TO 34
      NSC = MSAVE(IY(I))
      IF(NSR.EQ.O.DR.NSC.ED.O) GO TO 30
      BHH(NSR,NSC) = XY(1)
      GO TO 30
   34 CONTINUE
      NSC = MSAVE(IY(1))
      IF(NSR.EQ.O.OR.NSC.EQ.O) GO TO 30
      MHH(NSR.NSC) = XY(1)
   30 CONTINUE
   21 CONTINUE
C
C
      IF( IBK . NE . 1) GO TO 63
      REWIND 3
      WRITE (3) (((INERTA(1.J.N), 1=1.6), J=1.6), N=1.NJOINT)
      WRITE (3) (X(N), Y(N), Z(N), N=1, NJOINT)
      IF(.NOT.LPUNCH) GO TO 10
      WRITE (7,600) (IGRID(N), X(N), Y(N), Z(N), N=1, NJOINT).
   10 CONTINUE
      WRITE(6.507)
      DO 64 N=1.NJOINT
      WRITE (6.501) N. (GRID(N)
      WRITE (4.502)
      WRITE (6.503) X(N).Y(N).Z(N)
      WRITE (6.504)
      WRITE (6.503) (([NERTA([.J.N).J=].6).[=].6)
   64 CONTINUE
      WRITE (6.510)
      GO TO 22
   63 IF(IRK.NE.2) GO TO 65
      WRITE (3) (((PHI(I.N.J).i=1.6).J=1.MSTOTL).N=1.NJOINT)
      IFI.NOT. LPUNCH) GO TO A7
      DO 68 JEL.MSTOTL
      WRITE (7,600) (IGRID(N), (PHI(1,N,J), 1=1,3), N=1, NJOINT)
```

```
68 CONTINUE
   67 CONTINUE
      WRITE (6.114) NTAPE
      DO 17 I=1.NMODES
      IF(MSAVE(1).EQ.0) GO TO 17
      WRITE (6.115) MSAVE(1).1
   17 CONTINUE
      WRITE (6.510)
      DO 66 N=1.NJOINT
      WRITE (6,501) N. IGRID(N)
      WRITE (6.505)
      WRITE (6.503) ((PHI(I.N.J).I=1.6).J=1.MSTOTL)
   66 CONTINUE
      WRITE (6.510)
      GO TO 22
   65 IF(18K.NE.3) GO TO 69
      WRITE (3) ((KHH(I,J),I=1,MSTOTL),J=1,MSTOTL)
      WRITE (6.506)
      WRITE (6.503) ((KHH(1.J).J=1.MSTOTL).I=1.MSTOTL)
      WRITE (6.510)
      GO TO 22
   69 IF(IBK.NE.4) GO TO 77
      WRITE (3) ((BHH([.J).[=1.MSTOTL).J=1.MSTOTL)
      WRITE (6,508)
      WRITE (6,503) ((BHH(I,J),J=1.MSTOTL),I=1.MSTOTL)
      WRITE (6,510)
      GO TO 22
   77 IF(18K.NE.5) GO TO 22
      WRITE (3) ((MHH(I,J),I=1,MSTOTL),J=1,MSTOTL)
      WRITE (6.509)
      WRITE (6.503) ((MHH(1.J).J=1.MSTOTL).I=1.MSTOTL)
      WRITE (6.510)
   22 CONTINUE
C
                    DATA READY FOR DISCOS PROCESSING
C
      CALL DISCOSTIGRID. NJOINT. MSTOTL. ITAPE. LECHOL
      CALL NAODZ (IGRID.NJOINT.MSTOTL.ITAPE.LECHO.HINGE)
      IF(ITAPE.LE.A) GO TO 1
      STOP
      END
      SUBROUTINE DISCOSTIGRID.NJ.NM.ICNT.LECHO)
      IMPLICIT REAL . A-H.O-ZI
C
      LOGICAL LECHO
C
      RFAL ..
               X(500).Y(500).Z(500).INERTA(A.6.500).IRUNNO
      RFAL .R
               PHI(6,500,12),KHH(12,12),RHH(12,12),LOC(6)
      REALOR
               AMS(6).JMASS(500.1).JINER(500.6).AIN(6).SMM(6)
      RFAL . R
               SMSM(500.3).LOCA(500.3).MOD(6.6).AMD(500.13).KH(6).HH(6)
      REAL®8 AMP(500.72)
      COMMON /WORK/ AMP
      EQU'VALENCE (AMP(1.1).X(1))
      EQUIVALENCE (AMP(1,2),Y(1))
     EQUIVALENCE (AMP(1.3).2(1))
```

```
EQUIVALENCE (AMP(1.4), INERTA(1.1.1))
      EQUIVALENCE (AMP(1.1), PHI(1.1.1))
C
      INTEGER IGRID (500)
C
      COMMON /WORK2/ AMD
      EQUIVALENCE (AMD(1.1).JMASS(1.1)).
                                             (AMD(1,1), JINER(1,1))
      EQUIVALENCE (AMD(1.7), SMSM(1.1)).
                                             (AMD(1.10).LOCA(1.1))
      EQUIVALENCE (AMD(1.13), KHH(1.1)), (AMD(145,13), BHH(1.1))
C
      DATA
               IFST/O/
      DATA
               AMS/6HJMASS1.6HJMASS2.6HJMASS3.6HJMASS4.6HJMASS5.
                   6HJMASS6/
      DATA
              FLX/6HFLXDAT/
      DATA
              AIN/6HINERT1.6HINERT2.6HINERT3.6HINERT4.6HINERT5.
                   6HINERT6/
      DATA
               SMM/6HSTMSM1.6HSTMSM2.6HSTMSM3.6HSTSMS4.6HSTMSM5.
                   6HSTMSM6/
      DATA
               LOC/6HLOCATI, 6HLOCAT2, 6HLOCAT3, 6HLOCAT4, 6HLOCAT5,
     ٠
                   6HLOCAT6/
      DATA
           . HOD/6HXDIS1 ,6HYDIS1 ,6HZDIS1 ,6HTHA11 ,6HTHA21 ,6HTHA31
     .
                . SEAHTHA: STANTHA, STANTHA: STOCHO, STOCHOLO, STOCKO
     ٠
                . 6HXDIS3 .6HYDIS3 .6HZDIS3 .6HTHA13 .6HTHA23 .6HTHA33
     ٠
                . HEAHTHA. +6HTHALA .6HTHALA .6HTHALA .6HTHALA
     ٠
                . 6HTHA35 ,6HTHA15 ,6HTHA15 ,6HTHA35 ,6HTHA35
                6 CANTHA: 6 CANTHA: 61 CHYDISG . 6HTHA: 621 CYHO. 621 CXHO
      DATA
             KH/6HKHH1
                        ,6HKHH2 ,6HKHH3 ,6HKHH4
                                                   ·6HKHH5
                                                             · 6HKHH6
                                                                      1
                                 .6HBHH3
      DATA
             ВН/6НВНН1
                        · 6HBHH2
                                          , 6HBHH4
                                                    · 6HBHH5
                                                             · 6HBHH6
                                                                       1
      DATA IRUNNO/6HPREPRS/
C
  700 FORMAT (A6.1 0
                         14PREPRS '1
C
C
               INITIALIZE TAPE. START COUNTER
      REWIND 3
      IF(IFST.NE.O) GO TO 1
      CALL INTAPE(2.FLX)
      ICNT . 0
      IFST . 1
    1 CONTINUE
      ICNT = ICNT+1
C
C
                    PROCESS MASS MATRIX DATA
      READ
            (3) (((INERTA(I.J.N).[=1.6).J=).6).N=1.NJ)
      READ
           (3) (X(N),Y(N),Z(N),N=1,NJ)
      DO 2 1=1,NJ
      IF(INERTA(1.1.1).NE.INERTA(2.2.1)) GO TO 3
      IF(INERTA(2.2.1).NE.INERTA(3.3.1)) GO TO 3
      IF( INERTA(3,3,1).LT.0) GO TO 3
      JMASS(1.1) . INERTA(3.3.1)
      GO TO 2
    3 WRITE(6,500) 1.([NERTA([[.]].[].[].[].])
  500 FORMAT ( * ERROR MASS MATRIX POINT '. 15. ' JMASS = '.3E20.10)
      JMASS(1,1) = (INERTA(1,1,1)+INERTA(2,2,1)+INERTA(3,3,1))/3.000
    2 CONTINUE
                    PUNCH READ MATRIX INPUT CARD
C
                    PUT MASS MATRIX ON TAPE
     WRITE(7.700) AMS(ICNT)
      IFILECHO) CALL WRITE(JMASS.NJ.1.AMS(ICNT).500)
     CALL WTAPE(JMASS.NJ.1.AMS(ICNT).500.2)
```

```
C
                     PROCESS INERTIA DYAD DATA
      DO 4 1=1.NJ
       JINER(1.1) = INERTA(4.4.1)
      JINER(1.2) = INERTA(5.5.1)
      JINER(1.3) = INERTA(6.6.1)
      JINER(1,4) = -INERTA(4,5,1)
      JINER(1.5) =- [NERTA(4.6.1)
    4 JINER(1.6) =- INERTA(5,6,1)
      WRITE(7.700) AIN(ICNT)
      IF(LECHO) CALL WRITE(JINER, NJ, 6, AIN(ICNT), 500)
      CALL WTAPE(JINER.NJ.A.AIN(ICNT).500.2)
C
C
                     PROCESS STATIC MASS MOMENT DATA
C
                     PROCESS JOINT LOCATION DATA
      DO 5 1=1.NJ
      SMSM(1.1) =
                   INERTA(2.6.1)
      SMSM(1.2) = - [NERTA(1.6.1)
      SMSM(1.3) =
                   INERTA(1,5,1)
      LOCA(1,1) =
                   X(1)
      LOCA(1.2) =
                   YIII
    5 LOCA(1.3) = Z(1)
      WRITE(7,700) SMM(ICNT)
      IFILECHO) CALL WRITE(SMSM .NJ. 3. SMM(ICNT).500)
      CALL WTAPE(SMSM.NJ.3.SMM([CNT).500.2)
      WRITE(7,700) LOC(ICNT)
      IFILECHO) CALL WRITE(LOCA .NJ.3.LOC(10NT).500)
      CALL WTAPE(LOCA, NJ. 3. LOC(ICNT), 500.21
C
C
                     PROCESS MODAL DATA
      READ
            (3) (((PHI(1.N.J),I=1.6).J=1.NM).N=1.NJ)
      DO 6 K=1.6
      DO 7 I=1.NJ
      DO 7 M=1.NM
    7 AMD(1.M) = PHI(K. [.M)
      WRITE(7.700) MOD(K.ICNT)
      IF(LECHO) CALL WRITE(AMD, NJ.NM. MOD(K. ICNT). 500)
      CALL WTAPE(AMD, NJ.NM. MOD(K. [CNT). 500.2)
    6 CONTINUE
C
C
                     MODAL MATRICES
      READ
            (3) ((KHH([,J),[=1,NM),.!=1,NM)
            (3) ((RHH([,J),[=],NM),J=],NM)
      WRITE(7,700) KHIICNT)
      IFILECHO) CALL WRITE(KHH.NM.NM.KH(ICNT).12)
      CALL WTAPE(KHH.NM.NM.KH([CNT).12.2)
      WRITE(7,700)
                    BHILCHTE
      WRITE(6.100)
      IFILECHO) CALL WRITE(BHH, NM, NM, RH(ICNT).12)
      CALL WTAPE(BHH.NM.NM.BH([CNT).12.2)
C
      CALL LTAPE(2)
      CALL RTAPE(IRUNNO.AMS(ICNT).AMD.NJ.1.500.12.2)
      CALL WRITE(AMD.NJ.1.AMS(ICNT).500)
      CALL RTAPE(IRUNNO, AIN(ICNT), AMD, NJ.6, 500, 12, 2)
      CALL WRITE(AMD.NJ.6.AIN(ICNT).500)
      CALL RTAPE(IRUNNO.SMM(ICNT).AMD.NJ.3.500.12.2)
      CALL WRITE(AMD.NJ.3.SMM(ICNT).500)
      CALL RTAPE(IRUNNO, LOC(ICNT), AMO, NJ. 3, 500, 12, 2)
      CALL WRITE(AMD, NJ. 3. LOC(ICNT).500)
      DO 8 K=1.6
```

```
CALL RTAPE(IRUNNO, MOD(K, ICNT), AMD, NJ, NM, 500, 12, 2)
    A CALL WRITE(AMD.NJ.NM.MOD(K.ICNT).500)
      CALL RTAPE(IRUNNO, KH(ICNT), KHH, NM, NM, 12, 12, 2)
      CALL WRITE (KHH.NM.NM.KH(ICNT).12)
      CALL RTAPE(IRUNNO.BH(ICNT).BHH.NM.NM.12.12.2)
      CALL WRITE(BHH, NM, NM, BH(1CNT), 12)
  100 FORMAT ( 11 . 5x . ****** PROCESSED LUMPED PARAMETER AND MODAL DATA N
     OW ON DATA SET 2 (DISCOS INPUT TAPE) ******* .///)
      RETURN
      END
      SUBROUTINE NBODZ (IGRID.NJ.NM.ICNT.LECHO.HINGE)
      COMPUTE RESULTANT MODE DEPENDENT PARAMETERS FOR N-HOD2
C
      IMPLICIT REAL . (A-H.O-Z)
C
      LOGICAL LECHO
      COMMON /WORK/
      REAL *8 AMP(500.72)
      COMMON /WORK2/ AMD
      REAL . 8 AMD(500.13)
C
               AMS(6).FLX.AIN(6).SMM(6).LOC(6).MOD(6.6).KH(6).HH(6)
      REAL .B
               JMASS(500). JLOC(3,500). CMLOC(3). JINERT(3,3,500).
      REAL .B
               PHIT(3,500,12), PHIR(3,500,12).
                                                 SMO(3.500).
               FLOM(12). ZETA(12). BDINER(3.3).
               FLA(3.12). FLB(3.12). FLC(3.12). FLD(3.3.12).
               FLJ(3.3.12).
               FCF(3.3.12.12), FCK(3.12.12).
               TEM(3). TEM1(3.3). ADM(500.12.6). TEM(3).
               KHH(12.121. HHH(12.121. INUNNO
      INTEGER
               IGH ID (500)
      INTEGER
               HINGE. INTH
0
      DATA
               . AMS/AHJMASSI. AHJMASS2. AHJMASS3. AHJMASS4. AHJMASS5.
                   LAZZABIL WA
      DATA
              AIN/AHINERTI.AHINERT2.AHINERT3.AHINERT4.AHINERT5.
                   AHINERTA!
      DATA
               SMM/AHSTMSMI. AHSTMSMZ. AHSTMSMZ. AHSTSMS4. AHSTMSMS.
                   AHSTMSMA/
      DATA
               LOC/OHLOCATI. OHLOCATZ. OHLOCATZ. OHLOCATA. OHLOCATA.
     .
                   ANI OCATAL
      DATA
            . IEANTHA. ISANTHA. ISANTHA. ISIOSHA. ISIOYHA. ISIOXHA, ISIOXHANON
     .
                . SEMTHA. SSAHTHA. SIAHTHA. SZIOSHA. SZIOYHA.
     æ
                . EEAHTHA. ESAHTHA. ESAHTHA. ESINYMA. ESINYHA.
     -
                . AEAHTHA. ASAHTHA. ALAHTHA. ASINSHA. ASINSHA.
     .
                . AHTHAS . AHTHAS . AHTHAS . AHTHAS . AHTHASS .
                1 AEANTHA. ASANTHA. ALAHTHA. AZIONHA. AZIONHA. AZIOXHA
                        · 64KHH2 . 64KHH3 . 64KHH4
                                                    . AHKHHS
      DATA
             KH/ SHK HH!
                                                             . AHKHHA
                                                                       1
      DATA
             HHAHHA/HH
                        · AHAHH?
                                  EHHAHA.
                                           . AHRHHA
                                                     · AHHHHS
                                                              · AHHHHA
      DATA IRUNNO/6HPREPE
C
      FOUTVALENCE (AMP(1. 1).PHIT(1.1.1)).(AMP(1.37).PHIM(1.1.1)).
                   (AMF(1. 1).ADM(1.1.11).
                   (AMP(1.13).ADM(1.1.2)).
```

```
(AMP(1.25).ADM(1.1.3)).
     .
                   (AMP(1.37), ADM(1.1.4)),
     .
                   (AMP(1.49).ADM(1.1.5)).
                   (AMP(1,61),ADM(1,1,6))
      EQUIVALENCE (AMD(1.1), JMASS(1)), (AMD(1.2), JLDC(1.1)).
                   (AMD(1.5).SMD(1.1)). (AMD(1.5).JINERT(1.1.1))
C
C
         FIND INTERNAL NASTRAN NUMBER ASSOCIATED
C
         WITH THE HINGE POINT (GRID POINT 'HINGE')
      DO 1 N=1.NJ
      IF(IGRID(N).ED.HINGE) GO TO 2
    1 CONTINUE
      WRITE(6,100) HINGE
      RETURN
    2 INTH = N
C
C
                    INTH = INTERNAL MASTHAN NUMBER
C
                           OF HINGE POINT
c
C
          GET DATA OFF OF TAPE 2 TO COMPUTE CENTER OF MASS
C
      CALL RTAPE(IRUNNO.LOC(ICNT).AMP.NJ.3.500.72.2)
C
C
               JLOC(I.N) = I-TH COORDINATE OF GRID POINT IGRID(N)
C
                           VECTOR RELATIVE TO HINGE POINT HINGE
      DO 3 N=1.NJ
      DO 3 1=1.3
      JLOC(I,N) = AMP(N,I) - AMP(INTH,I)
    3 CONTINUE
C
      CALL RTAPE(IRUNNO.AMS(ICNT).AMP.NJ.1.500.72.2)
C
C
              JMASS(N) = LUMPED MASS AT GRID POINT IGRID(N)
      DO 4 N=1.NJ
      JMASS(N) = AMP(N.1)
    4 CONTINUE
C
      IF(.NOT.LECHO) GO TO 17
      WRITE(6.101)
      WRITE(6,102) (N.IGRID(N).N.(JLOC(I.N).I=1.3).N.JMASS(N).N=1.NJ)
   17 CONTINUE
C
C
         COMPUTE CENTER OF MASS LOCATION
      TOTMAS = 0.0
      CMLOC(1) = 0.0
      CMLOC(2) = 0.0
      CMLOC(3) . 0.0
C
C
          READ GRID POINT INERTIA TENSORS AND MASS MOMENTS
C
      CALL RTAPE(IRUNNO.SMM(ICNT).AMP.NJ.3.500.72.2)
```

DO 11 N=1.NJ

```
DO 11 1=1.3
       SMO(I,N) = AMP(N,I)
       IF(SMO(I.N).EQ.0.0) GO TO 11
       WRITE(6,107) (N.(SMO(I,N), [=1,3))
   11 CONTINUE
       IFILECHO) CALL WRITE(SMO,3,NJ,6H SMO ,3)
C
      CALL RTAPE(IRUNNO, AIN(ICNT), AMP, NJ, 6,500,72,2)
      DO 10 N=1.NJ
       JINERT(1,1,N) = AMP(N,1)
      JINERT(1,2,N) = -AMP(N,4)
      JINERT(1.3.N) = -\Delta MP(N.5)
      JINERT(2,1,N) = -\Delta MP(N,4)
      JINERT(2.2.N) = \Delta MP(N.2)
      JINERT(2,3 N) = -AMP(N.6)
      JINERT(3.1.N) = -\Delta MP(N.5)
      JINERT(3.2.N) = -\Delta MP(N.6)
      JINERT(3.3.N) = \Delta MP(N.3)
   10 CONTINUE
      IF(LECHO) CALL WRITE(JINERT.9.NJ.6HJINERT.9)
C
C
C.
C
      COMPUTE UNDEFORMED BODY INERTIA TENSOR
C
        RELATIVE TO BODY CENTER OF MASS
C
      00 20 1=1.3
      Dn 20 J=1.3
   20 BDINER(I,J) = 0.0
      DO 19 N=1.NJ
      CALL VECSUB(JLOC(1.N), CMLOC, TEM)
      CALL SUEOP(TEM. TEM. JMASS(N), TEM1)
      CALL DYADD (BDINER . TEMI . BDINER)
      CALL DYADD(BDINER.JINERT(1.1.N).BDINER)
   19 CONTINUE
C
C
C
           READ IN MODE SHAPES AND RESORT THEM
C
      DO 6 1=1.6
      CALL RTAPE(IRUNNO.MOD([.1CNT).ADM([.1.1]).NJ.NM.500.12.2)
    6 CONTINUE
      REWIND 3
      WRITE (3) (((ADM(N,M,1),1=1,3),N=1,NJ),M=1,NM)
      WRITE (3) (((ADM(N.M.1).1=4.6).N=1.N.)).M=1.NM)
      REWIND 3
      READ (3) (((PHIT(I.N.M).I=1.3).N=1.NJ).M=1.NM)
      READ (3) (((PHIR(I.N.M).I=1.3).N=1.NJ).M=1.NM)
      REWIND 3
C
      IF(.NOT.LECHO) GO TO 18
      WRITE(6.104)
      DO 7 M=1.NM
      WRITE(6.105)
      WRITE(6.106)
                      (N.M.(PHIT(I.N.M). I=1.3).
                       N.M. (PHIR([.N.M), [=].3).N=].NJ)
    7 CONTINUE
   IR CONTINUE
C
      W" ITE(A.118)
```

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```
WRITE(6,103) TOTMAS
      WRITE(6,115)
      WRITE(6,119) (BDINER(1,J),J=1,3)
      WRITE(6,120) (BDINER(2,J),J=1,3)
      WRITE(6,121) (BDINER(3,J),J=1,3)
      WRITE(6,115)
      WRITE(6,122) (CMLOC(I), I=1,3)
      WRITE(6,115)
      WRITE (6,125) INTH, HINGE
      WRITE (6,115)
C
          COMPUTE RESULTANT PARAMETERS
C
C.
      DO 8 M=1.NM
      DO 8 1=1,3
      FLA(I,M) = 0.0
      FLB(I,M) = 0.0
      FLC(I,M) = 0.0
      Dn 8 J=1,3
      FLJ(I,J,M) = 0.0
      FLD(I,J,M) = 0.0
    8 CONTINUE
      DO 9 M=1.NM
      DO 9 MM=1,NM
      DO 9 1=1,3
      FCK(I,M,MM) = 0.0
      DO 9 J=1.3
      FCF(I,J,M,MM) = 0.0
    9 CONTINUE
C
C
      AMASS = 1.0/TOTMAS
C
      DO 12 M=1,NM
      DO 13 J=1,NJ
C
      CALL SCLV(JMASS(J), PHIT(1, J.M), TEM)
      CALL VECADD(FLA(1,M),TEM,FLA(1,M))
C
      CALL VECSUB(JLOC(1.J).CMLOC.TEM)
      CALL SUEOP(PHIT(1.J.M).TEM.JMASS(J).TEM1)
      CALL DYADD(FLD(1,1,M),TEM1,FLD(1,1,M))
C
      CALL VECROS(JLOC(1,J),PHIT(1,J,M),TEM)
      CALL SCLV(JMASS(J), TEM, TEM)
      CALL VECADD(FLB(1.M).TEM.FLB(1.M))
C
      IF(JINERT(1.1.J).EQ.O.O.AND.
         JINEPT(2,2,J).EQ.0.0.AND.
         JINERT(3,3,J).EQ.O.O) GO TO 13
C
      CALL DYDOTV(JINERT(1.1.J), PHIR(1.J.M), TEM)
      CALL VECADD(FLC(1,M),TEM,FLC(1,M))
C
      CALL VECXDY(PHIR(1,J,M),JINERT(1,1,J),TEM1)
      CALL DYADD(FLJ(1,1,M),TEM1,FLJ(1,1,M))
   13 CONTINUE
C
C
         RESULTANT UNCOUPLED MODE DEPENDED PARAMETERS
C
```

```
C
  100 FORMAT (1X. ** ERROR ** CANNOT FIND HINGE POINT , 15, IN GRID P
     *OINT TABLE, RETURN OUT OF SUBROUTINE NBOD21)
  101 FORMAT (////, GRID POINT LABELING, LOCATION AND MASS TABLES',//)
  'JMASS(', 14, ') = ', E15.7)
    5 CONTINUE
      \Delta = 1.0/TOTMAS
      CALL SCLV(A, CMLOC, CMLOC)
C
      DO 5 N=1.NJ
      TOTMAS = TOTMAS + JMASS(N)
      CALL SCLV(JMASS(N), JLOC(1,N), TEM)
      CALL VECADD(CMLOC, TEM, CMLOC)
    8 Y(I) = X(I+1)
      NY = 3
      NR = 1Y(3)
      RETURN
    7 IF(IFORM.NE.307) GO TO 9
      IY(1) = NR+1
      Y(1) = X(1)
      NY = 1
      NR = X(2) * FAC
      IF(NR.ED.O) RETURN
     1Y(2) = NR
      Y(2) = X(3)
      NY = 2
      NR = X(4)*FAC
      IF(NR.ED.O) RETURN
      NR = NR-1
      RFTURN
    9 IF(IFORM.NE.308) GO TO 10
      NR = X(1) *FAC
      IF(NR.EQ.O) GO TO 14
      DO 11 I=1,3
      IY(I) = NR-1+I
   11 \ Y(I) = X(I+1)
      NY = 3
      NR = IY(3)
      RETURN
   10 IF(IFORM.NE.309) GO TO 12
      NR = X(1)*FAC
      IF(NR.EQ.O) GO TO 14
      DO 13 I=1.2
      IY(I) = NR-1+I
   13 \ Y(I) = X(I+1)
      NY = 2
      NR = X(4)*FAC
      IF(NR.EQ.O) RETURN
      NR = NR-1
      RETURN
  103 FORMAT (' XMAS =', E15.7, 30X, ' (TOTAL MASS OF BODY)')
  104 FORMAT (////, MODE SHAPE TABLE (INTERNAL NUMBERING) 1.//)
  105 FORMAT (///)
  106 FORMAT (' PHIT(',14,',',12,') =',3E15.7,5X,
             PHIR(',14,',',12,') =',3E15.7)
  107 FORMAT (///, WARNING MASS MOMENT AT GRID POINT NON-ZERO, THAT IS
    * SMM ',14,') =', 3E15.7,/,' THIS EFFECT IGNORED BY N-BOD2. N-BOD2
     * ASSUMES EACH GRID POINT AT ELEMENT MASS CENTER ')
```

```
108 FORMAT (' FLA(', 12, ') = ',3E15.7, ' (COEFFICIENT TO FIND CENTER OF
   * MASS LOCATION AFTER DEFORMATION)')
109 FORMAT (' FLB(', I2, ') = ',3E15.7, ' (COEFFICIENT TO FIND ANGULAR M
   *OMENTUM DUE TO DEFORMATION)')
110 FORMAT ('
              FLC(',12,') = ',3E15.7,' (COEFFICIENT TO FIND ANGULAR M
   *OMENTUM DUE TO DEFORMATION)')
111 FORMAT ('
              FLD(', I2,') = ',3E15.7)
112 FORMAT ('
              FLJ(',12,') = ',3E15.7)
113 FORMAT (' FCF(', I2,',', I2,') =',3E15.7)
114 FORMAT (' FCK(',12,',',12,') =',3E15.7,' (COEFFICIENT FOR CORIDLI
   *S TORQUE DUE TO DEFORMATION) )
115 FORMAT ('
               • )
116 FORMAT (/,3x,'FOR MODE',13,' THE RESULTANT UNCOUPLED MODE DEPENDEN
   *T PARAMETERS REQUIRED FOR N-8002 INPUT ARE')
117 FORMAT (/,3x, FOR MODES',13, AND',13, THE RESULTANT MODE DEPENDE
   *NT CROSS COUPLING PARAMETERS REQUIRED FOR N-BOD2 INPUT ARE!)
118 FORMAT ('1',5X,'***** RESULTANT FLEXIBLE BODY DATA REQUIRED FOR IN
   *PUT TO N-BOD2 ******,///)
                                 (UNDEFORMED INERTIA TENSOR OF THE!)
119 FORMAT ('
                     ',3E15.7,'
120 FORMAT ('
               ΧI
                    =',3E15.7,'
                                  FLEXIBLE BODY IN BODY COORDINATES!)
121 FORMAT ('
                    ',3E15.7,'
                                  RELATIVE TO BODY CENTER OF MASS) )
122 FORMAT ('
                   =',3E15.7,' (CENTER OF MASS VECTOR, HINGE POINT T
              CA
   *0 CM) ')
123 FORMAT (
              FLOM(',12,') =',E15.7,' RAD/SEC
                                                (MODAL FREQUENCY) )
124 FORMAT (
              ZETA(',12,') =',E15.7,'
                                                (MODAL DAMPING ZETA)')
125 FORMAT (' CB
                   = VECTOR IN CONTIGUOUS BODY TO HINGE POINT DEFINED
   * AT INTERNAL GRID POINT', 15, ' (EXTERNAL GRID POINT', 15, ' IN BULK D
   *ATA) 1)
126 FORMAT (' FLD(', I2, ') = ',3E15.7, ' (COEFFICIENT TO FIND INERTIA T
   *ENSOR AFTER DEFORMATION)')
127 FORMAT (' FLJ(', 12,') = ',3E15.7,' (COEFFICIENT FOR CENTRIPITAL T
   *ORQUE DUE TO DEFORMATION)')
128 FORMAT (' FCF(',12,',',12,') =',3E15.7,' (COEFFICIENT FOR CENTRIP
   *ITAL TORQUE DUE TO DEFORMATION)')
    RETURN
    END
```

SUBROUTINE INTERP(INPT.IMAT)

```
THIS ROUTINE SETS UP A CODE SEQUENCE WHICH WILL BE USED
C
       TO READ MIXED INTEGER AND FLOATING POINT DATA FROM
C
C
       THE DMI CARDS
       ALANK FIELD ON LAST CARD WILL BE INTERPRETED AS AN INTEGER
C
C
       BUT READ LATER IN AS ZERO, A CHECK FOR WHICH IS MADE
C
      INTEGER INPT(80)
      DATA IDOT, IEE/1H., 1HE/
      IF(INPT(12).EQ.IDOT.AND.INPT(21).EQ.IEE) GO TO 1
      IF(INPT(44).EQ.IDOT.AND.INPT(53).EQ.IEE) GO TO 2
      IMAT = 310
                               310 - FORMAT I.E.I.E
C
      RETURN
    2 IF(INPT(60).EQ.IDOT.AND.INPT(69).EQ.IEE) GO TO 3
      IMAT = 309
C
                               309 - FORMAT I.E.E.I
```

C

```
RETURN
    3 IMAT = 308
C
                               308 - FORMAT I.E.E.E
      RETURN
    1 IF(INPT(28).EQ.IDOT.AND.INPT(37).EQ.IEE) GO TO 4
      1 (INPT(60).EQ.IDOT.AND.INPT(69).EQ.IEE) GO TO 5
      IMAT = 307
C
                              307 - FORMAT E.I.E.I
                                                      OR
                                                           E
      RETURN
    5 IMAT = 306
C
                               306 - FORMAT E.I.E.E
      RETURN
    4 IF(INPT(44).EQ.IDOT.AND.INPT(53).EQ.IEE) GO TO 6
      IMAT = 305
C
                              305 - FORMAT E.E.I.E OR E.E
      RETURN
    6 IF(INPT(60).EQ.IDOT.AND.INPT(69).EQ.IEE) GO TO 7
      IMAT = 304
C
                              304 - FORMAT E.E.E.I DR
                                                          E . E . E
      RETURN
    7 IMAT = 303
C
                              303 - FORMAT E.E.E.E
      RETURN
      END
      SUBROUTINE DECODE (IFORM, X, NR, Y, IY, NY)
C
C***
          ERROR IN TERMINOLOGY ELEMENTS COMING IN BY ROWS.
C
             NR AND IY(I) REFER TO COLUMN NUMBER
C
C
         OUTPUT OF DECODE
C
                    = NUMBER OF REAL NUMBERS ON DMI CARD
              NY
C
              IY(I) = ROW LOCATION FOR I-TH REAL NUMBER ON DMI CARD
C
              Y(I) = I-TH REAL NUMBER
                    = NEXT REAL NUMBER TO BE PUT IN ROW NR+1 UNLESS
C
              NR
C
                      FIELD 1 OF NEXT CARD CONTAINS AN INTEGER
C
      REAL *8 X(4), Y(4)
      INTEGER IY(4)
      FAC = 1.00001D+08
      IF(IFORM.NE.303) GO TO 1
      DO 2 I=1.4
      IY(I) = NR+I
    2 Y(I) = X(I)
      NY = 4
      NR = IY(4)
      RETURN
    1 IF(IFORM.NE.304) GO TO 3
      DO 4 I=1.3
      IY(I) = NR+I
    4 Y(I) = X(I)
      NY = 3
      NR = X(4)*FAC-1
      RETURN
    3 IF(IFORM.NE.305) GO TO 5
```

```
00 6 I=1.2
     IY(I) = NR+I
   6 Y(I) = X(I)
     NY = 2
     NR = X(3) *FAC
     IF(NR.EQ.O) RETURN
     IY(3) = NR
     Y(3) = X(4)
     NY = 3
     RETURN
   5 IF(IFORM.NE.306) GO TO 7
     IY(1) = NR+1
     Y(1) = X(1)
     NY = 1
     NR = X(2) \neq FAC
     IF(NR.EO.O) RETURN
     DO 8 1=2.3
     IY(I) = NR-2+I
  12 IF(IFORM.NE.310) GO TO 14
     NR = X(1) *FAC
     IF(NR.EO.O) GO TO 14
     IY(1) = NR
     Y(1) = X(2)
     NR = X(3) *FAC
     IF (NR. EQ. O) RETURN
     IY(2) = NR
     Y(2) = X(4)
     NY = 2
     RETURN
  14 WRITE(6,100) IFORM
 100 FORMAT ( ! IFORM = 1, 15, ! ERROR!)
     STOP
     END
     SUBROUTINE INTAPE (NTAPE, TAPEID)
     REAL*8 TAPEID, BUF, EDT
     DATA IZ1, BUF, EOT/1, 0.D 0, 3HEOT/
    DATA NOT / 6/
 INITIALIZE TAPE FOR SURROUTINE WTAPE.
CALLS FORMA SUBROUTINE PAGEND.
CODED BY RF HRUDA. JULY 1968.
REVISED BY R A PHILIPPUS. APRIL 1969.
    SUBROUTINE ARGUMENTS (ALL INPUT)
 NTAPE = NUMBER OF TAPE. (E.G. 10).
 TAPEID = TAPE IDENTIFICATION. (E.G. T1234). (A6 FORMAT).
2001 FORMAT (//// 14H LOGICAL UNIT 12, 7H, TAPE A6,
                  23H. HAS BEEN INITIALIZED.)
    REWIND NTAPE
     WRITE (NTAPE) TAPEID, IZ1, EOT, (BUF, I=1,16)
    REWIND NTAPE
```

C

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C

INTERNAL VARIABLES THAT ARE PUT ON TAPE (TRANSFERRED THRU COMMON).

IRUNNO IS RUN NUMBER OF PROBLEM. (A6 FORMAT).

DATE IS DATE. (A6 FORMAT). FOR EXAMPLE 15FE65.

IF (NRA .LT. 1 .OR. NCA .LT. 1) GO TO 999

C SEARCH TAPE FOR END OF WRITTEN DATA.

10 READ (NTAPE) TAPEID.LN, IEOTCK

IF (IEOTCK .EO. EOT) GO TO 20

READ (NTAPE)

GO TO 10

C

C

C

END OF WRITTEN DATA HAS BEEN FOUND.

20 BACKSPACE NTAPE

WRITE (NTAPE) TAPEID, LN, BUF, IRUNNO, ANAME, NRA, NCA, DATE, DENSE,

* (BUF, I=1,10)

WRITE (NTAPE) ((A(I,J), I=1, NRA), J=1, NCA)

LN = LN + 1

WRITE (NTAPE) TAPEID, LN, EDT, (BUF, I=1,16)

```
BACKSPACE NTAPE
      RETURN
C
  999 WRITE (NOT, 1000)
 1000 FORMAT (1H1.43HERROR IN SUBROUTINE WTAPE, PROGRAM STOPPED.)
      STOP
      END
      SUBROUTINE LTAPE (NTAPE)
      REAL * B TAPEID, IRUNNO, ANAME, IEOTCK, DATE, ITYPE, ICHK, EOT,
          DENSE, SPARSE, SPART
          DATA NOT / 6/
          DATA EDT. DENSE, SPARSE, SPART / 3HEDT, 5HDENSE, 6HSPARSE, 5HSPART/
C
C
  LIST HEADINGS OF MATRICES ON TAPE.
C
   CALLS FORMA SUBROUTINE PAGEND.
C
   CODED BY RF HRUDA. JULY 1968.
                                     REVISED NOVEMBER 1970.
C
   REVISED BY R A PHILIPPUS. APRIL 1969.
C
C
      SUBROUTINE ARGUMENTS (ALL INPUT)
C
   NTAPE = NUMBER OF TAPE. (E.G. 10).
C
 2001 FORMAT (//36x35HLISTING OF MATRICES ON LOGICAL UNITI3.7H, TAPE A6)
 2002 FORMAT (//30x35HLISTING OF MATRICES ON LOGICAL UNIT13,7H, TAPE A6,
              12H (CONTINUED))
 2003 FORMAT (27X69(1H-)/27X3HNO.3X7HRUN NO.4X4HNAME5X5HNROWS4X5HNCOLS4X
     4
              4HDATE6X3HNNZ3X9HPARTITION/
                27X3H---3X6H-----4X6H-----4X5H----
                4x5H----- / )
 2004 FORMAT (25x15,3x46,4x46,3x15,4x15,4x46,3x15,3x14,1H/14)
 2005 FORMAT (/27X12HEND OF LIST.)
C
      REWIND NTAPE
      READ (NTAPE) TAPEID
      REWIND ITAPE
      L=0
C
   12 CONTINUE
      IF(L .ED. 0) WRITE (NOT, 2001) NTAPE, TAPEID
      IF(L .NE. 0) WRITE (NOT.2002) NTAPE.TAPEID
      WRITE (NOT.2003)
      NL INE = 1
   13 L=L+1
      READ (NTAPE) TAPEID, LN, IEOTCK, IRUNNO, ANAME, NR, NC, DATE, ITYPE, NNZ,
                   NP, NPT
      IF (L .EQ. 1)
                    ICHK = IRUNNO
      IF (ICHK .EQ. IRUNNO) GO TO 15
      NLINE=NLINE+1
      WRITE (NOT, 2004)
      ICHK = IRUNNO
   15 IF (IEOTCK .EO. EOT) GO TO 30
      READ (NTAPE)
                       DENSE ) WRITE (NOT.2004)
      IF (ITYPE .EQ.
                               LN. IRUNNO. ANAME. NR. NC. DATE
```

```
IF (ITYPE .EQ.
                         DENSE ) GO TO 20
      IF (ITYPE .EQ.
                         SPARSE) WRITE (NOT. 2004)
                                  LN. IRUNNO. ANAME. NR. NC. DATE. NNZ
      IF (ITYPE .EQ.
                         SPARSE) GO TO 20
      IF (ITYPE .EQ.
                         SPART ) WRITE (NOT.2004)
                                  LN. IRUNNO. ANAME.NR. NC. DATE. NNZ. NP. NPT
                         SPART ) GO TO 20
      IF (ITYPE .EQ.
      WRITE (NOT, 2004) LN, IRUNNO, ANAME, NR, NC, ITYPE
   20 NLINE=NLINE+1
      IF(NLINE.GT.43) GO TO 12
      GO TO 13
C
   30 WRITE (NOT, 2004) LN, 1EOTCK
      WRITE (NOT, 2005)
      REWIND NTAPE
      RETURN
      END
      SUBROUTINE RTAPE (IARUNO.IANAME. A.NRA.NCA. KR.KC.NTAPE)
      REAL * A . IARUNO . IANAME . TAPEID . IEOTCK . ITRUNO . ITNAME .
              DATE . ITYPE . DENSE . EOT
      DIMENSION A(KR.1)
      DATA NOT / 6 /
      DATA DENSE.EDT / SHDENSE.3HEDT /
   READ MATRIX A FROM TAPE BY IDENTIFICATION OF IARUNO-IANAME.
   CALLS FORMA SUBROUTINES LTAPE, PAGEND, ZZHOMB.
   CODED BY WA BENFIELD. JUNE 1966.
   LAST REVISION BY R F HRUDA. SEPTEMBER 1971.
C
      SUBROUTINE ARGUMENTS
   IARUNO = INPUT RUN NUMBER OF MATRIX A. (A6 FORMAT).
IANAME = INPUT MATRIX IDENTIFICATION. (A6 FORMAT).
A = OUTPUT MATRIX READ FROM TAPE. SIZE(NRA,NCA).
   NRA
          = DUTPUT NUMBER OF ROWS OF MATRIX A. WILL BE READ FROM TAPE.
          = OUTPUT NUMBER OF COLS OF MATRIX A. WILL BE READ FROM TAPE.
   NCA
C
   KR
          = INPUT ROW DIMENSION OF A IN CALLING PROGRAM.
          = INPUT COL DIMENSION OF A IN CALLING PROGRAM.
C
   KC
   NTAPE = INPUT NUMBER OF TAPE. (E.G. 10).
 3001 FORMAT (29HIRTAPE CANNOT FIND
                                        RUNNO = \Delta6 /
               21X 8HANAME = A6 / 29X 6H----- )
C
      NTIME = 0
   SEARCH TAPE FOR CORRECT HEADING.
    5 READ (NTAPE) TAPEID, LN, IEOTCK, ITRUNO, ITNAME, NRA, NCA, CATE, ITYPE, NNZ
      IF (ITRUNO .EQ. IARUNO .AND. ITNAME .EQ. IANAME) GO TO 10
      IF (IEOTCK .EQ.
                         EOT) GO TO 20
      READ (NTAPE)
      GO TO 5
   MATRIX HAS BEEN FOUND.
```

10

```
NERROR=1
      IF (ITYPE .NE. DENSE .AND. NNZ .NE. 0) GO TO 999
                                                            NERROR=2
      IF (NRA.GT.KR .DR. NCA.GT.KC) GO TO 999
      READ (NTAPE) ((A(1.1).1=1.NRA).J=1.NCA)
      RETURN
C
  MATRIX CANNOT BE FOUND. SEARCH TAPE ONCE MORE.
   20 NTIME = NTIME+1
                                                            NERROR = 3
      IF (NTIME .EO. 2) GO TO 998
      REWIND NTAPE
      on to 5
  9" 8 WRITE (NOT. 3001) IARUNO, IANAME
  999 CALL LTAPE (NTAPE)
      WRITE (NOT. 3002) NERROR
 3002 FORMAT (1H1.43HERROR IN SUBROUTINE RTAPE. PROGRAM STOPPED.
             10H NERROR = .131
      STOP
      EMD
      SUBROUTINE WRITE (A.NR.NC.ANAME.KR)
      REAL ** A. ANAME
      DIMENSION A(KR.1)
      DATA NOT / 6/
C
   WRITE MATRIX OF REAL NUMBERS ON PAPER.
   REQUIRES 123 COLUMN (MINIMUM) PRINTER.
0
  HP TO 10 DATA FIELDS PER LINE. PRINTS ONLY MON-ZERO FIELD ROWS.
   CALLS FORMA SUBROUTINE PAGEND.
   CODED BY RE WOHLEN. DECEMBER 1968.
C
C
C
      SUBROUTINE ARGUMENTS (ALL INPUT)
C
         = MATRIX TO BE PRINTED. SIZE(NR.NC).
         = NUMBER OF ROWS IN MATRIX A.
C
   NR
        = NUMBER OF COLS IN MATRIX A.
C
   ANAME = MATRIX IDENTIFICATION. (A6 FORMAT).
         = ROW DIMENSION OF A IN CALLING PROGRAM.
C
 2010 FORMAT 1//15H OUTPUT MATRIX A6.2X 1H(14.2H X 14.2H ) //
             10x,10(7x,1H( 12,1H))/)
 2020 FORMAT (//15H OUTPUT MATRIX A6.2X 1H(14.2H X 14.2H )
              3x, 9HCONTINUED //10x,10(7x,1H( 12,1H))/)
 2030 FORMAT (1x.215.2x.1P10011.3)
 2040 FORMAT (14HOEND OF WRITE.)
   PULL UP A NEW PAGE FOR MATRIX AND PRINT MATRIX NAME.
C
      WRITE (NOT. 2010) ANAME.NR.NC. (L.L=1.10)
      NI 1NF = 0
0
      DO 60 1=1.NR
      NZFRD = 0
      15 = 1
   10 JF = JS+9
```

```
IF (JE .GT. NC) JE=NC
C SEE IF ELEMENTS ARE ZERO.
      DO 20 J=JS.JE
      IF (A(I,J) .NE. O.D 0) GO TO 30
   20 CONTINUE
      GO TO 40
   30 NLINE = NLINE+1
      IF (NLINE .LE. 44) GO TO 35
      WRITE (NOT. 2020) ANAME.NR.NC. (L.L=1.10)
      NLINE = 1
   35 WRITE (NOT, 2030) I, JS, (A(1, J), J=JS, JE)
      NZERO = 1
   40 IF (JE .EQ. NC) GO TO 50
      JS = JS+10
      GO TO 10
 SKIP A SPACE BETWEEN EACH ROW IF THERE ARE MORE THAN 10 COLUMNS
C AND SOMETHING HAS BEEN WRITTEN.
   50 IF (NC.LE.10 .OR. NZERO.ED.O .OR. I.ED.NR) GO TO 60
      NLINE = NLINE+1
      WRITE (NOT.2030)
   60 CONTINUE
C
      WRITE (NOT, 2040)
      RETURN
      END
```

SUBROUTINE VECADD(V1, V2, S)

C ADDS VECTOR V1 TO V2 RESULT IN S
IMPLICIT REAL +8(A-H, O-2, \$)
DIMENSION V1(3), V2(3), S(3)

S(1) = V1(1) + V2(1)

S(2) = V1(2) + V2(2)

S(3) = V1(3) + V2(3)

RETURN
END

SUBROUTINE VECSUB(V1, V2, D)

SUBTRACTS VECTORS V1-V2=D

IMPLICIT REAL *8(A-H, O-Z, \$)

DIMENSION V1(3), V2(3), D(3)

D(1) = V1(1) - V2(1)

D(2) = V1(2) - V2(2)

D(3) = V1(3) - V2(3)

RETURN

END

```
SUBROUTINE SCLV(SC,V,P)

C SCALAR * VECTOR
IMPLICIT REAL*B(A-H,O-Z,S)
DIMENSION V(3),P(3)
P(1) = SC*V(1)
P(2) = SC*V(2)
P(3) = SC*V(3)
RETURN
END
```

SUBROUTINE VECDOT(V1, V2, D)

C VECTOR DOT PRODUCT
IMPLICIT REAL*8(A-H, O-Z, \$)
DIMENSION V1(3), V2(3)
D = V1(1)*V2(1) + V1(2)*V2(2) + V1(3)*V2(3)
RETURN
END

SUBROUTINE VECROS (V1,V2,C)

VECTOR CROSS PRODUCT C = V1 X V2

IMPLICIT REAL*8(A-H,O-Z,\$)

DIMENSION V1(3),V2(3),C(3)

C(1) = V1(2)*V2(3)- V1(3)*V2(2)

C(2) = V1(3)*V2(1)- V1(1)*V2(3)

C(3) = V1(1)*V2(2)- V1(2)*V2(1)

RETURN
END

SUBROUTINE TRIPVP(V1, V2, V)

COMPUTES STANDARD VECTOR TRIPLE PRODUCT

V = VIX(V1XV2) = V1*(V1.V2) - V2*(V1.V1)

IMPLICIT REAL*8(A-H,O-Z,\$)
DIMENSION V1(3),V2(3),V(3)
A = V1(1)*V2(1) + V1(2)*V2(2) + V1(3)*V2(3)
B = V1(1)*V1(1) + V1(2)*Y1(2) + V1(3)*V1(3)
V(1) = V1(1)*A - V2(1)*B
V(2) = V1(2)*A - V2(2)*B
V(3) = V1(3)*A - V2(3)*B
RETURN
END

C

C

C

C

```
SUBROUTINE DYADD(D1.D2.D)
C
      ADDS THO DYADS
              D = D1 + D2
      IMPLICIT REAL+8(A-H.O-Z.S)
      DIMENSION D1(3.3). D2(3.3). D(3.3)
      DO 1 1=1.3
      DO 1 J=1,3
    1 D(1.J) = D1(1.J) + D2(1.J)
      RETURN
      END
      SUBROUTINE SCLD(A.D.T)
      IMPLICIT REAL+8(A-H.O-Z.S)
      DIMENSION D(3.3).T(3.3)
      MULTIPLY SCALAR BY A TENSOR
      T(1.1) = A*D(1.1)
      T(2.1) = A*D(2.1)
      T(3.1) = A*D(3.1)
      T(1.2) = A*D(1.2)
      T(2.2) = A*D(2.2)
      T(3,2) = A*D(3,2)
      T(1.3) = A*0(1.3)
      T(2.3) = A*D(2.3)
      T(3.3) = A*D(3.3)
      RETURN
      END
      SUBROUTINE DYDOTV(A.V.D)
C
      SCALAR DOT PRODUCT OF DYAD AND VECTOR
C
                 D = A.V
      IMPLICIT REAL*8(A-H.O-Z.S)
      DIMENSION D(3).A(3.3).V(3)
      DO 1 1=1.3
      D(I) = 0
      DO 1 J=1.3
    1 D(1) = D(1) + A(1.J)*V(J)
      RETURN
      END
      SUBROUTINE VXDYDV(V1.DY.V)
      COMPUTES VECTOR X (DYAD . VECTOR)
C
              V = V1 X (DY . V1)
      IMPLICIT REAL * A ( A-H. N-Z. $)
      DIMENSION V1(3). V2(3). V(3). DY(3.3)
      DO 1 K=1.3
```

```
DO 1 J=1,3
    1 \ V2(K) = V2(K) + DY(K,J)*V1(J)
      V(1) = V1(2) * V2(3) - V1(3) * V2(2)
       V(2) = V1(3)*V2(1) - V1(1)*V2(3)
      V(3) = V1(1)*V2(2) - V1(2)*V2(1)
      RETURN
       END
       SUBROUTINE DYTOV (D.X1.X)
C
      USE TO TAKE SCALAR DOT PRODUCT OF TRANSPOSE OF
C
       TENSOR D WITH VECTOR X1
C
       NEEDED SINCE TENSORS IN SYMMERIC MATRIX OF INERTIA TENSORS ARE IN
C
          NON SYMMETRIC
       IMPLICIT REAL +8 (A-H.O-Z.S)
      DIMENSION D(3,3),X1(3),X(3)
       DO 1 I=1,3
       X(I) = 0
       Dn 1 J=1,3
       X(I) = X(I) + D(J,I)*X1(J)
     1 CONTINUE
       RETURN
       END
       SUBROUTINE VODYOV(V1.DY.V2.X)
C
        COMPUTES THE SCALAR TRIPLE PRODUCT
C
                     VECTOR . (DYAD . VECTOR)
                          V1.(DY.V2)
C
       IMPLICIT REAL +8 (A-H, 0-Z, $)
       DIMENSION V1(3), DY(3,3), V2(3), TEM(3)
       DO 1 K=1.3
       TEM(K) = 0.00
       DO 1 J=1,3
     1 \text{ TEM(K)} = \text{TEM(K)} + \text{DY(K,J)} \neq \text{V2(J)}
       X = 0
       DO 2 J=1.3
     2 \times = \times + V1(J)*TEM(J)
       RETURN
       END
       SUBROUTINE DYOP (V.D)
C
       TRANSFORMS VECTOR VI INTO SKEW DYAD
       IMPLICIT REAL +8 (A-H, 0-Z, $)
       DIMENSION V(3).D(3.3)
       D(1.1) = 0
       D(1,2) = V(3)
```

V2(K) = 0.00

```
RETURN
       END
       SUBROUTINE SUEOP(V1, V2, XM, D)
       IMPLICIT REAL*8(A-H, 0-Z, $)
       DIMENSION V1(3), V2(3), D(3,3)
C
       USED TO COMPUTE THE PSUEDO INERTIA TENSOR
CCC
        OF BODY LAMBA WITH RESPECT TO THE ORIGIN OF NEST K-1 AND
        THE HINGE POINT I-1 WHICH IS ON THE TOPOLOGICAL PATH FROM
        BODY 1 TO BODY LAMBA
C
           BLOCK G SUPPER GAMBA, SUB K-1, I-1 EQUATION 2-55 OF X-732-71-70
C
                      D = XM*((V1.V2)*1 - V2 V1)
C
C
          XM - SCALAR
C
          V1 - VECTOR
C
          V2 - VECTOR
C
           1 - UNIT DYAD
           * - SCALAR MULTIPLICATION
C
C
           . - VECTOR SCALAR MULTIPLICATION
C
       BLANK - TENSOR MULTIPLICATION
C
       NOTE THAT, IN GENERAL THE PSUEDO INERTIA TENSOR IS NON SYMMETRIC
C
       D(1,1) = XM*(V1(2)*V2(2) + V1(3)*V2(3))
       D(1,2) = -XM * V2(1) * V1(2)
       D(1,3) = -XM*V2(1)*V1(3)
       D(2,1) = -XM + V2(2) + V1(1)
       D(2,2) = XM + (V2(1) + V1(1) + V2(3) + V1(3))
       D(2,3) = -XM*V2(2)*V1(3)
      D(3,1) = -XM * V2(3) * V1(1)
       D(3,2) = -XM + V2(3) + V1(2)
       D(3,3) = XM*(V2(1)*V1(1) + V2(2)*V1(2))
       RETURN
       END
       SUBROUTINE VECXDY(P,T,D)
      REAL*8 P(3), T(3,3), D(3,3)
C
C
          COMPUTES VECTOR CROSS DYAD
C
                    D = P X T
      D(1,1) = P(2)*T(3,1) - P(3)*T(2,1)
      D(1,2) = P(2)*T(3,2) - P(3)*T(2,2)
      D(1,3) = P(2)*T(3,3) - P(3)*T(2,3)
      D(2,1) = P(3)*T(1,1) - P(1)*T(3,1)
```

D(1,3) = -V(2) D(2,1) = -V(3) D(2,2) = 0 D(2,3) = V(1) D(3,1) = V(2) D(3,2) = -V(1) D(3,3) = 0

```
D(2,2) = P(3)*T(1,2) - P(1)*T(3,2)

D(2,3) = P(3)*T(1,3) - P(1)*T(3,3)

D(3,1) = P(1)*T(2,1) - P(2)*T(1,1)

D(3,2) = P(1)*T(2,2) - P(2)*T(1,2)

D(3,3) = P(1)*T(2,3) - P(2)*T(1,3)

RETURN

END
```

REFERENCES

- McCormick, Caleb W., "The NASTRAN User's Manual," NASA Document SP-222, September 1970.
- 2. Douglas, Frank J., "The NASTRAN Programmer's Manua!," NASA Document SP-223, September 1970.

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